
INCAS

**INtegrated model for the
Competitiveness
Analysis of
Small-medium sized reactors**

Ver.1.1

POLIMI-mar2010



***USER'S MANUAL
&
TEST CASES***



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NOTE: This documentation and the corresponding copy of the INCAS code Ver.1.1 are given to IAEA - NENP and PESS – as a pilot version of the software, for application, evaluation, debug and development purposes and for IAEA internal use only.



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INTRODUCTION

The INtegrated model for the Competitiveness Analysis of Small-medium sized reactors (INCAS) is a Matlab code that allows the user to run scenario simulations about nuclear investment projects in new reactor fleets.

INCAS code allows the user great flexibility in the input parameters setting to represent different investment strategies and scenario conditions (electricity price, operating performances, sources of financing, etc.).

In this way, sensitivity analysis are possible, to appreciate the impact of each input variable on the economic performance on the investment project or to set the most suitable investment strategy to reach the project objectives: i.e. LCOE minimisation, profitability maximisation., risk control, etc.

INCAS measures several indicators of performances, under different perspectives: financial soundness, cost-effectiveness, profitability, etc.

The user is allowed to save the scenario input settings, in order to recover them and, in case, modify selected parameters, running the program with new input values.

INPUT SECTION – Standard User Input

The user is asked to open, alternatively, an existing investment scenario input file, or an investment scenario including input+output data, or to define the input for a new investment scenario.

INCAS input section is based on four input categories:

1. reactor library
2. investment specific inputs
3. country specific inputs
4. construction strategy.

The user defines these inputs by editing the appropriate data in subsequent specific windows.

At this point INCAS offers the option to save the scenario inputs and start the data processing or just to run the program without saving the inputs.

A third option allow the user to enter an “Advanced User Input” interface, where an expert user may modify some constitutive features of the model and some calculation options.

At the end of the input section the file INIT_I.m performs the association of each reactor-type of the new fleet with its specific-data set.

The file INIT_II provides other variables definition and initialisation for Income Statement and Balance Sheet accounting calculations.

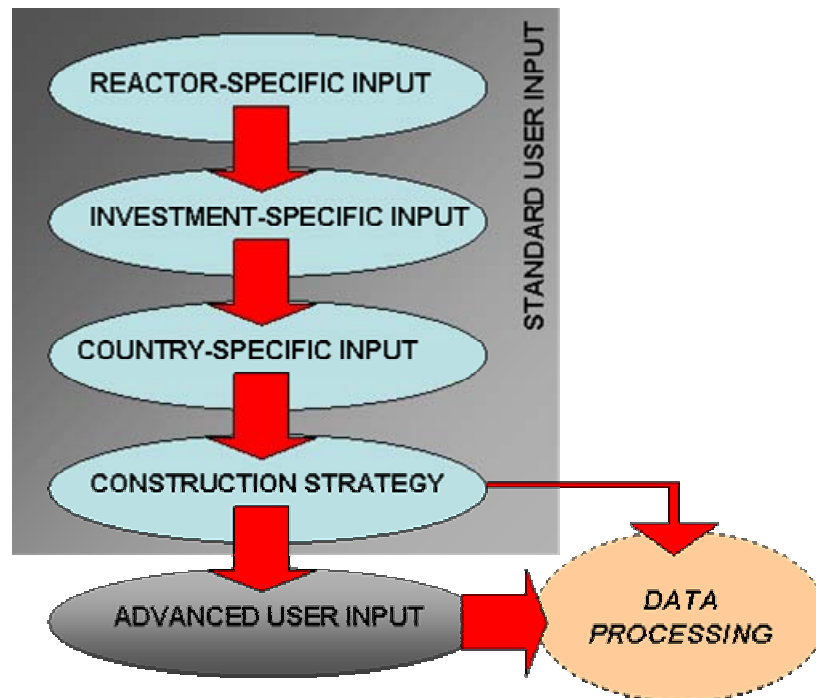


Fig.1. User's input section of INCAS code:

Reactor library:

A library of different reactor-types, each with its specific technical and economical data-set is included in the INPUT.m file.

INCAS also enables the user to define new reactor-types to be used in the scenario simulation.

If a new scenario is defined or an existing input file is open to be modified, INCAS shows a default library of reactor design technologies and asks the user either to check and validate the data-set of each reactor type (with the option to modify it), or to define a new reactor-type with its specific technical/economical parameters.

In this case, a windows opens for the user to enter the data-set of the new reactor type.

The reactor library is then up-dated.

- ✓ Power output [MWe]
- ✓ Expected duration of construction [numbers of quarters]
- ✓ Capacity factor: ratio of actual power output on nominal power output
- ✓ Operating life [years]
- ✓ Operation & maintenance unit cost [Cur/kWh]
- ✓ Fuel cycle unit cost [Cur/kWh]
- ✓ Decontamination & Decommissioning unit cost [Cur/kWh]
- ✓ Design saving factor [%]
- ✓ Number of reactors of the same type already built in the world at time zero
- ✓ Years since deployment of last reactor of the same type in the world
- ✓ Share of overnight costs that is affected by a delay in construction schedule.

Each of the above mentioned data is specific to a given reactor-type.

Thus ‘Design saving factor’ is a factor < 1 that represents a cost saving due to technical simplification and enhancements specific to the reactor concept as compared to an hypothetical, standard generation III LWR of the same size.

The ‘Number of reactors of the same type already built in the world’ is necessary to calculate the learning effect on the construction phase: a learning effect is accumulated both at worldwide and site level and reduces the construction unit costs.

Learning decays with time passing: a linear decay law has been assumed that depends on the years passed since the construction of the last unit of the same type, in the world or in the site.

INCAS is able to calculate automatically the on-site learning effect, on the base of the construction strategy defined by the user in a further input section.

The ‘Share of overnight costs that is affected by a delay in the construction schedule’ is represented by building-yard and labour costs on total construction costs (including materials and equipment); the idea is that such costs are unavoidable during a construction delay and increase with the time employed.

INCAS ver 1.1 offers some default values for these inputs, that are to be considered purely demonstrative.

Investment-specific input:

These input variables are specific to the investment strategy and to the consequent financial conditions.

The mix of financing includes the two major categories of Equity and Debt; other sources of financing as bonds or shares traded on the stock exchange, export financing, etc. may be assimilated either to Debt or Equity, each with its related cost of capital.

Re-investment share deals with investment self-financing capability: multiple plants deployment offer the chance to employ cash flows generated from early units in the financing of later units.

Shareholders have the option to specify the share of such cash inflow that will be re-invested in the project, the rest being earned as dividends.

Debt amortization period and cost of debt are conditions that shareholders of the project negotiate with lenders (i.e. Banks) on the basis of the mix of financing and of the project risk: as an example, the Olkiluoto 3 project benefit of very low cost of debt on the back of long-term sale contract for the electricity and export credit guarantees, that lower the business and financial risks.

Cost of Equity is set in order to represent the minimum capital remuneration rate required by shareholders to invest in the project, rather than employ their capital alternatively.

Cost of Equity and Debt are strongly influenced by business and financial risk, that’s to say market, operational and financial conditions. Thus they have to be set by the user, well aware that they have to be consistent with the specific investment project characteristics and conditions.

In this way, several investment project schemes and strategies may be represented, from a cooperative model such as Olkiluoto 3, to a more liberalized market model, to a state-controlled market framework.

- ✓ number of reactors
- ✓ number of sites
- ✓ cost of equity [%]
- ✓ re-investment share [%]
- ✓ financing mix [%]: Equity/(Equity+Debt)
- ✓ debt amortization period [years]
- ✓ cost of debt [%]

- ✓ average depreciation period for fixed assets [%]
- ✓ overnight construction cost for a reference, standard, large LWR [Cur/kWe]
- ✓ power output for the reference, standard, large LWR [MWe]
- ✓ annual escalation rate for construction costs [%].

Country-specific input:

This set of variable defines a specific country scenario in terms of electricity market, financial market, tax issues:

- ✓ electricity price [Cur/MWh]
- ✓ electricity price annual increase rate [%]
- ✓ risk free rate [%]
- ✓ annual inflation rate [%]
- ✓ corporate tax rate [%]

Electricity price is determined on the basis of an initial value at time $t=0$ (corresponding to the start of construction of the first plant) and an annual increase rate. This trivial linear model for the price of electricity might be refined by dedicated electricity forecast models to be linked to INCAS.

Short term risk-free-rate represents the expected investment remuneration of D&D funds invested in short-term risk-free assets, as for example government bonds.

Inflation rate applies on each operating cost.

Construction strategy:

At this point the number of reactor-plants to be deployed and the number of nuclear sites have been defined by the user.

The construction strategy is defined by the user by associating each reactor of the new fleet to a design-type, a site location, a beginning period for its construction and its actual duration of construction.

The “actual” duration of construction may be different from the “expected” duration of construction of each specific reactor-type (n-th unit): in this way the user is able to simulate construction delays that may have a significant impact on the economic performances of the investment project. A relevant delay in the construction of the first units may result in a relevant increase of the LCOE of the entire fleet and in a relevant decrease of the financial profitability.

The location strategy of the plants on the national nuclear sites has a relevant effect as well on the economics as far as the capital costs are considered. Learning affects may arise from the construction of multiple units of the same type: in particular, “on-site” learning and “worldwide” learning may be calculated, where the former concerns the expertise that is developed by deploying multiple units of the same type on the same site and the latter refers to the expertise that may be built by deploying multiple units of the same type in different sites of a country. Clearly the on-site learning has a heavier impact in reducing the construction cost of subsequent units of the same type on the same site.

Moreover, multiple units on the same site share fixed costs, thus decreasing the construction costs of later units.

All this considered, INCAS has an original feature that allow to include in the scenario elaboration the impact of the construction strategy in terms of timing and siting.

INPUT SECTION – Advanced User Input

INCAS relays on proprietary models that calculates:

- ✓ the learning accumulation in the construction and assembling of the NPP,
- ✓ the modularisation saving factors that deals with the standardisation and the factory fabrication of the equipment and reduce the unit construction cost depending on the size of the plant,
- ✓ the multiple-units-on-a-single-site economies that are mostly relates to the fixed cost sharing on site.

The Advanced User Input interface let the user free to change the model parameters for the calculation of the above mentioned factors.

In particular, on-site and worldwide learning accumulation curves may be reshaped depending on the users' definition of the cost saving related to each doubling of the power installed on-site or worldwide. The user may define two different curves for worldwide and on-site learning accumulation and the combined cost saving factor lays on a surface depending on the number of reactors of the same type, previously built in the world or on the same site as the current NPP.

INCAS modularisation curve relates to the III+ generation of NPP, that are designed to be “modular”. Modularisation cost savings depend on the size of the NPP: the lower the size, the higher and easier is the modularisation and the related cost savings.

But traditional, generation III NPP that are not conceived to be “modular” cannot lay on the same modularisation curve. Their modularisation factor is expected to lay outside and above the corresponding modularisation factor value for a “modular” reactor of the same size.

INCAS modularisation curve is defined for “modular”, generation III+ NPP, between 35MWe and 1100MWe, where the factor attains 100%.

Therefore, it is not possible just to extend the INCAS default curve to catch the modularisation factor for an EPR (1600MWe). The most correct approach concerning NPP that are not conceived to be “modular” is to input a new, different modularisation cost saving factor: thus EPR's modularisation factor is expected to be higher than 100%, meaning that the modularisation degree of an EPR concept is lower than an AP1000.

Fixed costs sharing on site is another major cost saving factor for multiple units built on the same site.

The user is asked to define the maximum cost saving for the n-th NPP unit built on the same site, as an asymptotic value, to reshape the cost saving curve.

At the end of this section, the user is allowed to change some options that deals with Internal Rate of Return and Levelised Cost Of Electricity calculation.

IRR is the rate of return of the investment project that depends on the discount rate applied to the calculation; the discount rate represents the capital remuneration rate required by the investors.



When the Net Present Value of the investment cash flows breaks even, then the corresponding discount rate is called IRR.

In the same way, LCOE is defined as the electricity price that breaks even the investment Net Present Value.

INCAS search for the IRR and the LCOE on a range of tentative values, that is spanned through a defined step width.

The most wide the range and the step inside the range, the lower is the data processing speed, but the higher will be the accuracy of the results.

Default values for these parameters are built-in, that may be changed by the user.

DATA PROCESSING

INCAS_MAIN.m and BLACK_BOX.m

The INCAS_MAIN file includes the logical structure of the code that run the data processing.

All the variables are represented by matrixes of $(n \times T)$ dimension, where n is the number of reactors in the NPP fleet and T is the total number of time-steps considered in the analysis: thus every variable has a specific value for a reactor “ i ” in a specific time-step “ t ”:

variable(i,t) is the element in the row “ i ”, column “ t ” of the $(n \times T)$ matrix variable

The data processing is run by two nested loops, the outer concerning the single time-step “ t ”, the inner concerning the reactor “ i ”.

Inside these loops, an iterative calculation process is run by the BLACK_BOX.m file.

Accounting values for Income Statement and Balance Sheet require the calculation of financial interest expenses and earnings; these values depend on the stock of debt and cash in the Balance Sheet.

But these stocks in turn, are influenced by the interest expenses and earnings: interest earnings are a source of income that increase cash stock and interest expenses are a cost item that has to be converted, if necessary, in new debt.

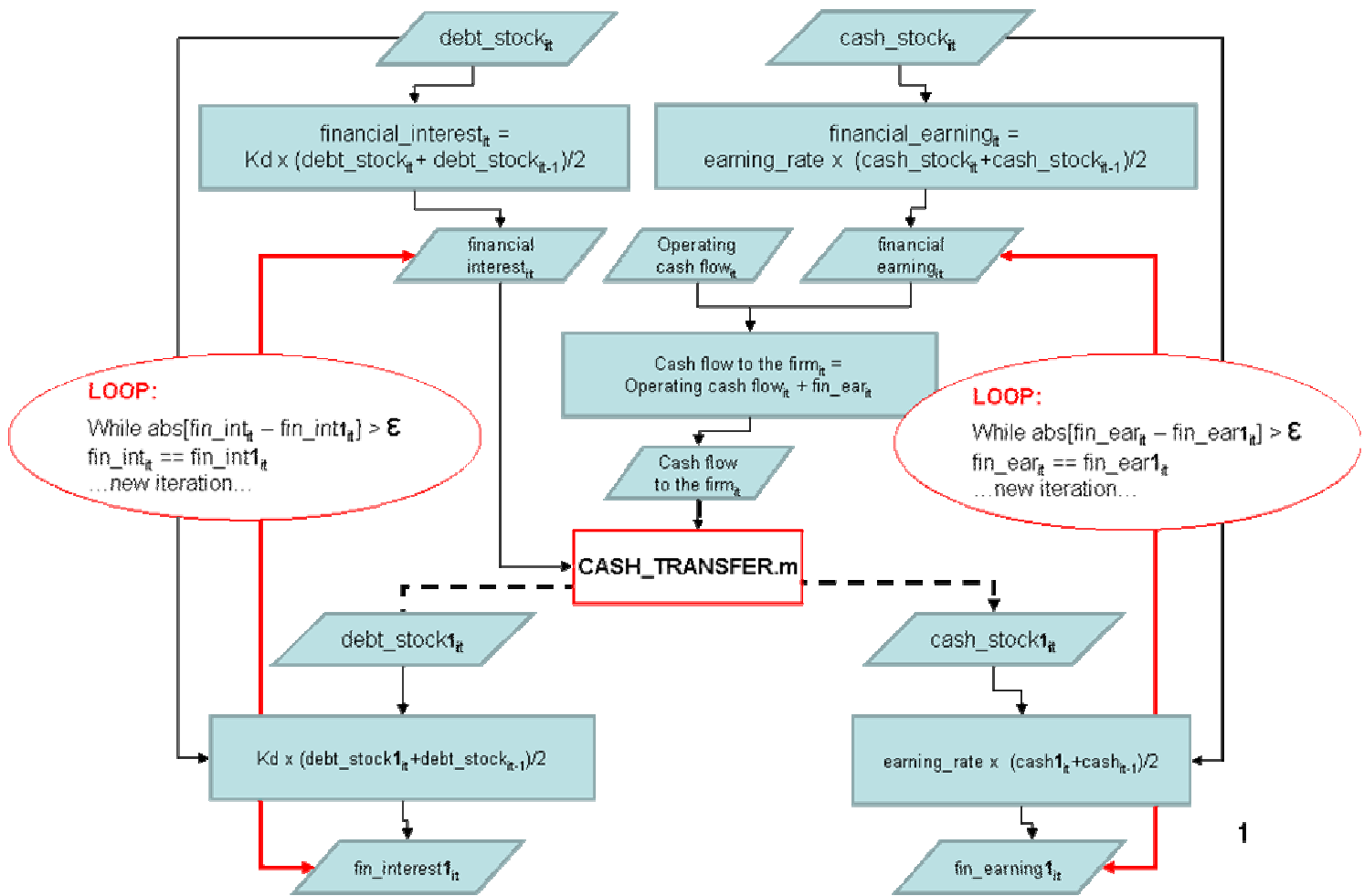


Fig.2. Logic structure of iterations based on financial interests expenses and earnings

Knowledge of the current period stock of debt and cash is then unknown until the iteration process' convergence through the free cash flow calculation. A first tentative calculation of interest expenses and earnings is run by FINANCIAL.m, on the basis of the initialized values of the debt and cash stock values ($db_stock(i,t)$ and $cash_stock(i,t)$).

Successively, INCAS calculates more refined results on the basis of up-dated stock values ($db_stock1(i,t)$ and $cash_stock1(i,t)$), as provided by CASH.TRANSFER.m file.

The file FINANCIAL1.m calculates the new tentative values for interest expenses and earnings on the basis of new values for debt and cash stocks. This iteration is based on the convergence of both financial interest and earnings values and is handled by the INCAS_MAIN.m file code (Figure 2).

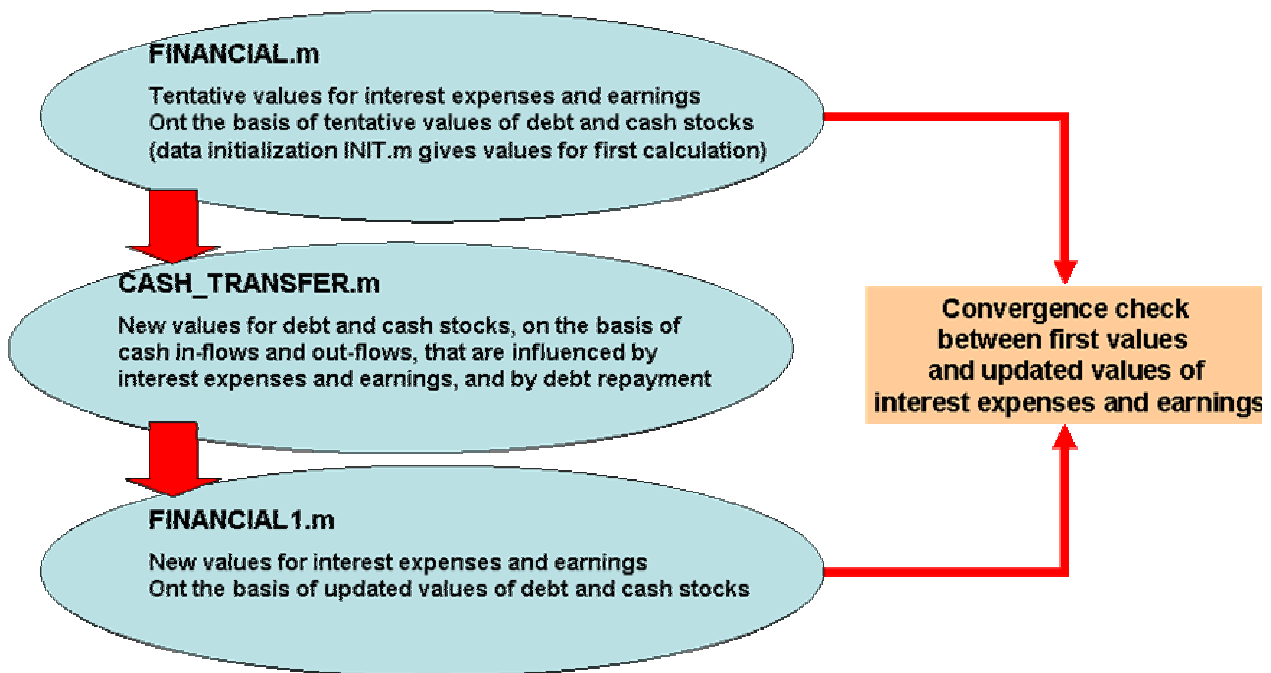


Fig.3. Files involved in the iteration process and their tasks

COUNTERS_new.m

The first function called by the main file is COUNTERS.m. This function calculates:

- ✓ number of reactors of the same type on the same site in the new fleet
- ✓ $\text{count3}(i,t)$ = number of reactors of the same type as reactor “i”, that are built on the same site as “i”, in the time-step “t” and that are considered in the learning curve calculation: the construction of the previous reactor-unit “i-1” has to be at least 1/3 completed when the construction of “i” starts
- ✓ $\text{NW}(i,t)$ = number of reactors of the same type as “i” in the world, elsewhere than the site of “i”.

INCAs calculates automatically the years from the end of construction of previous NPP to the beginning of construction of next NPP of the same type, either on the same site or worldwide, in order to feed the calculation of the learning effect.

A linear decay law for learning is actually defined both for worldwide learning (full decay in 10 years) and on-site learning (full decay in 5 years).

CAPITAL.COST.m

CAPITAL_COST.m assumes a reference overnight unit construction cost [Cur/kWe] that is provided as an input by the user and that relates to a reference reactor of a given size, same technology and n-th unit, specified as well by the user: i.e. 3,000 Cur/kWe for a 1000MWe standard LWR.

This variable is called `ref_CC`.

The unit overnight cost of the current reactor “i” of size MW(i) is derived by ref_CC by mean of a corrective factor C_factor(i,t), which is specific to the reactor “i” and is time-dependent.

C_factor includes:

1. the economy-of-scale effect on construction costs: scale(i,t)
2. the learning effect and its cost-saving impact: learning(i,t)
3. the modularization in the fabrication process and its associated cost-saving: modul(i,t)
4. the co-siting economies, that arise in case of multiple units on the same site: multiple(i,t)
5. the design-dependent factor that may decrease/increase the construction costs as compared to the reference reactor design (i.e. simplification of SMRs may result in a lower unit construction cost as compared to a standard LR): design(i,t)

1. scale(i) is calculated through the formula:

$$(MW(i)/ref_MW)^{(s-1)}$$

where:

MW(i) = size of current reactor “i”
 ref_MW = size of reference reactor
 s = scale factor (<1)

2. if the default learning curve is assumed, learning(i,t) factor for reactor ‘i’ is calculated as follows:

$$learning(i,t) = Keq * (NW(i,t) + count3(i,t))^{-\alpha} + Klab * (NW(i,t) + 1)^{-\beta2} * (count3(i,t))^{-\beta1} + Kmat * (count3(i,t))^{-\gamma}$$

where:

Keq, Klab, Kmat are the percentages of the equipment cost, labour cost and material cost on the total cost of the FOAK unit

$\alpha, \beta1, \beta2, \gamma$ are coefficients that account for the learning in factory equipment, labour learning on the site, labour learning in the world, learning about the utilization of materials.

NW(i,t) is the number of reactors of the same type as “i” in the world, elsewhere than the site of “i”.

count3(i,t) is the number of reactors of the same type as reactor “i”, on the same site as “i”, that are considered in the learning curve calculation (the construction of the previous reactor-unit “i-1” has to be at least 1/3 completed when the construction of “i” starts)

Both NW(i,t) and count3(i,t) are calculated by the COUNTERS_new.m file.

Otherwise, if a user-defined learning curve is assumed, combined learning effect (worldwide and on-site) for reactor ‘i’ is calculated as follows:

$$f(k,j) = a^{(\log2(count3(i,t)))} * b^{(\log2(NW(i,t)))}$$

where ‘a’ and ‘b’ are the cost saving factors (%) corresponding to a doubling of the power installed on the site and worldwide, respectively.

3. modul(i) is calculated on the base of a fourth degree polynomial formula that relates modularization savings to the size of the plant in terms of power output.

Otherwise, in the ‘Advanced User Input’ section, the user has the option to re-define new modularisation values corresponding to each reactor-type of the new fleet and overcome the default modularisation curve.

4. $\text{multiple}(i,t)$ is calculated by the formula:

$$(1 + (\text{count2}(i,t)-1) * (1-\text{asy}))/\text{count2}(i,t)$$

where $\text{count2}(i,t)$ is the number of reactors of the same type as “i” on the same site and is calculated by the COUNTER_new.m file; “asy” is the asymptotic saving that is reached when an infinite number of units is built on the same site. INCAS provides a default value of 14% that can be overcome by a different, user defined value, set in the ‘Advanced User Input’ section.

5. a design saving factor - $\text{design}(i,t)$ - is given as input by the user in the reactor-specific input section. In further development of the INCAS code, it might be calculated as a function of some relevant design features that have a major impact on the construction costs: m3 of concrete, tons of steel, number of large forged components, etc.

$$C_factor(i,t) = \text{scale}(i) * \text{learning}(i,t) * \text{modularization}(i) * \text{multiple}(i,t)$$

$C_factor(i,t)$ has a specific value for each successive reactor unit and, in particular, accounts for a cost decrease for the n-th unit as compared to the (n-1)th, all the rest being equal (design technology and size).

After the unit overnight construction cost calculation ($CC(i)=\text{ref_CC}*C_factor(i)$), total overnight cost for current reactor “i” ($\text{tot_capex}(i,t)$) is calculated given its size and its actual construction duration:

$$\text{tot_capex}(i,t) = \text{MW}(i)*CC(i)*(1-Y(i)) + \text{MW}(i)*\text{constr_duration}(i)*CC(i)*Y(i)/\text{ref_duration}(i)$$

where $\text{MW}(i)$ is the size of current reactor and $Y(i)$ is the percentage of construction costs that are supposed to increase (linearly) with a construction delay. The formula compares the actual construction duration with the estimated one, both given in input by the user.

The single period capital expenditure, is a fraction of total capital expenditures that is calculated following a “S-curve” cumulative spend pattern (“sine-curve” single period spend pattern) and including an escalation factor that represent a specific inflation rate for construction costs.

REVENUES.m

The file REVENUES.m calculates the single period revenues from the electricity sale as the product of GWh produced and the electricity price: the former depends on the size of the reactor in terms of electric output $\text{MW}(i)$ and capacity factor $\text{CF}(i)$ given as input by the user. The electricity price is modelled following a linear increase law, but it might result from a more detailed estimation model. The modularity of INCAS code structure allow subsequent refinements to every single part of the scenario modelling, as the “revenue model”

OP_RESULT.m

OP_RESULT.m calculates:

- ✓ the operating costs (operation and maintenance, fuel cycle and decontamination & decommissioning) on the basis of the user's unit costs input (€/MWh) and on the electric output of the single period
- ✓ the single period depreciation of fixed assets
- ✓ the earning before interest expenses and tax (EBIT) as:
$$ebit(i,t) = \text{revenues} - \text{operating costs} - \text{depreciation}$$

COST_CAPITAL.m

COST_CAPITAL.m calculates the interest earning rate for a short term financial investment, as applies to the Cash Sotck:

$$rfr_nominal = (1+rfr_real) * (1+infl) - 1$$

The cost of equity K_e and of debt K_d are given as inputs by the user.

Finally, the Weighted Average Cost of Capital (WACC) is calculated given the financing mix and the tax rate specified by the user in the input:

$$wacc = K_e * eq_share + K_d * (1-eq_share) * (1-tax_rate)$$

FINANCIAL.m and FINANCIAL1.m

The files FINANCIAL.m and FINANCIAL1.m calculate the interest expenses and earnings on the basis of the average of the current and previous period's values of debt / cash stocks respectively.

The interest expenses payment applies only after the commercial deployment of the NPP.

INCAS assumes the construction period as a “grace period” for interest expenses payment: in this period Interests During Construction are capitalized and increase debt stock and obligations.

NP.m

NP.m file calculates the net profit value for each reactor unit in each time period:

$$net_profit(i,t) = ebit(i,t) - fin_int(i,t) + IDC_offset(i,t) + fin_ear(i,t) * (1-tax_rate)$$

it has to be highlighted that the interest expenses cash outflow is compensated by the IDC_offset variable that assumes the opposite value of the interest expenses during the construction period and is zero elsewhere.

CASHFLOW.m

CASHFLOW.m file calculates the “cash flow to the firm” as the sum of all the cash outflows (capital expenditures related to the construction costs; taxes) and inflows (EBIT; depreciation, interest earnings).

ASSETS.m

ASSETS.m calculates the fixed asset value in the Balance Sheet as the cumulate value of the capital expenditure, decreased by the depreciation and increased by the IDC, during the construction period.

CASH_TRANSFER.m

CASH_TRANSFER.m represents a fundamental function for the INCAS CODE.

The philosophy is that in a multiple NPP investment project, with a staggered construction schedule, the cash surplus generated by the early deployed units from the electricity sale, may be transferred to the later units to finance their construction costs, thus reducing the amount of equity and debt disbursement by the investors.

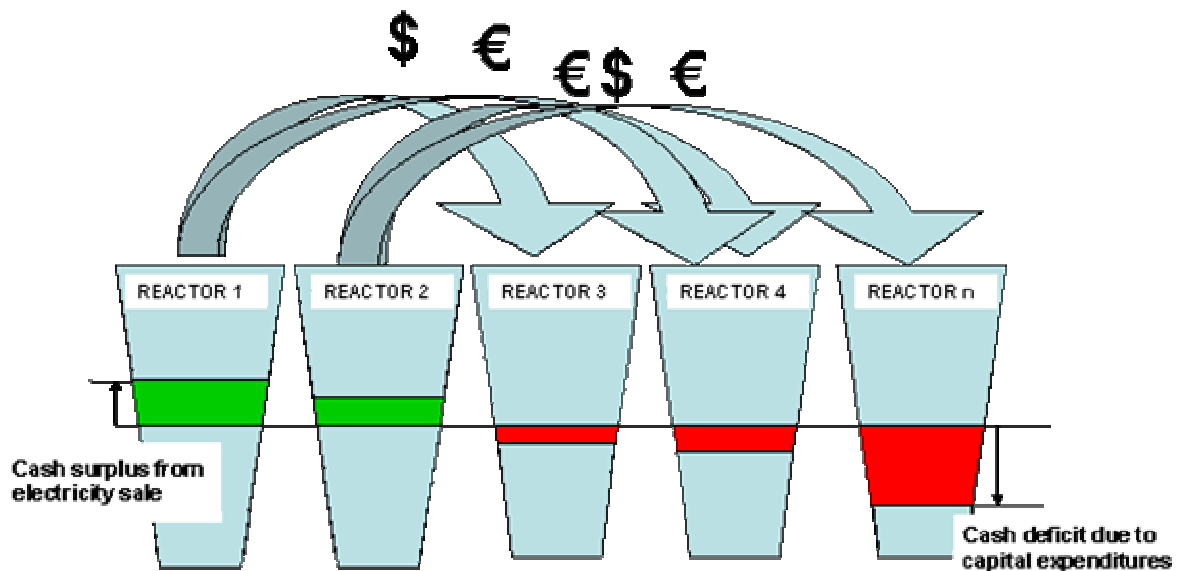


Fig.4. Cash transfer process between reactor plants of the new fleet

In a first step, the function checks if the current reactor “i” has a cash-flow surplus or deficit in the current period “t”: cash-flow deficit represent a current cash need mainly due to capital expenditures.

If the reactor “i” has a current cash-deficit ($cf_firm(i,t) < 0$), a routine is activated that checks if some of previous NPP (from $i=1$ to $i-1$) has a positive cash stock surplus (positive cash stock accumulates only after full debt repayment).

If it is the case, the current cash-deficit of reactor “i” may be totally or partially balanced by the cash surplus of “cash-rich” reactors.

Then, after the cash-transfer routine has been applied, two cases may occur:

1. $cf_firm(i,t)$ for current reactor is still negative: new debt and equity investment are needed to balance the negative cash-flow-to-the-firm, on the basis of the financing mix ratio.
Interest expenses will be included in the new debt investment and the resulting debt investment will increase the existing debt stock.
2. $cf_firm(i,t)$ for current reactor is ≥ 0 : in this case, new equity investment is not needed to cover any current cash deficit.
Because cash-flow-to-the-firm does not include interest expenses payment, this amount has still to be covered either by a surplus of $cf_firm(i,t)$, or it has to be financed by new debt investment. Two sub-cases are analyzed:
 - 2.a) positive cash-flow-to-the-firm is in excess of interest expenses of current period: it can cover interest expenses and there’s no need of new debt investment.
In this case cash flow excess, after interest expenses payment, it is possible to repay (partially or fully) the debt principal annual amortization.
Debt stock amortization plan is defined by the user in the investment-specific input section and determines the annual amortization quotas on the basis of the debt duration and the debt stock outstanding.
 - 2.b) cash-flow-to-the-firm is not able to cover interest expenses.
Interest expenses have to be financed by new debt investment, that will increase the existing debt stock. Cash stock will not be increased.

In this way, if a NPP generates a positive cash flow in a time-step (case 2.a), it may increase the Cash stock or it may finance later NPP units.

The user may define a share of this cash that will go to finance other NPPs, the balance going to repay shareholders in the form of “dividends”.

Cross-financing between NPPs is used either to pay the capital or to repay debt principal to debt-holders.



OUTPUT

The INCAS code is able to calculate the full set of accounting values for each reactor plant at each time-step: the accounting values are classified in the three main financial prospects indicated in the following table:

PROFIT&LOSS	CASH FLOW STATEMENT	BALANCE SHEET:
revenues	(-) EQUITY INVESTMENT	NET ASSETS
O&M costs	(+) EBIT	CASH
fuel costs	(+) DEPRECIATION	<hr/>
D&D	(-) TAX	EQUITY
depreciation	(+) INTEREST EARNINGS	DEBT
<hr/>	(-) INTEREST EXPENSES	
EBIT	(-) DEBT PRINCIPAL AMORTIZATION	
interest expenses	<hr/>	
interest earnings	FREE CASH FLOWS	
tax		
<hr/>		
NET PROFIT		

Profit&Loss (P&L) and Cash Flow (CF) statements refer to the current period values, while Balance Sheet (BS) deals with cumulated stocks of values.

P&L considers costs and revenues that are of competence of current fiscal period, while Cash Flow statement considers actual and effective cash outflows and inflows. The treatment of capital investment costs and depreciation is an example of the difference between the two logics.

Capital investment costs in fixed assets are not included in the P&L, but they are accounted in the CF statement as a cash outflow.

Depreciation is the cost item that refers to fixed assets in P&L, accounting for the annual-quota of decrease in value of the capital assets; it is a figurative cost, but does not correspond to an actual cash outflow. For this reason it is added back as a positive cash inflow in the Cash Flow statement, in order to compensate the EBIT figure (that was decreased by the depreciation amount in the P&L).

INCAS calculates the set of three financial statements (Profit & Loss statement, Cash Flow statement and Balance Sheet) at each NPP level; then, all the financial statements of the whole NPP fleet are consolidated to calculate global key financial indicators. Thus, these indicators are representative of the whole investment case:

- ✓ Internal Rate of Return
- ✓ Net Present Value
- ✓ LCOE
- ✓ PBT

Each of the above mentioned output will then refer to the NPP fleet investment project as a whole. Net Present Value is the sum of all cash out-flows and in-flows, discounted by an appropriate rate that represent the cost-opportunity of the capital employed. Thus NPV is a decreasing function of

the discount rate. If a discount rate is set, the corresponding NPV is to be considered as the excess value earned above the capital remuneration represented by the discount rate itself.

It means that if a 10% discount rate is assumed and 100M€ NPV is calculated, the investment project is able to generate 100M€ on top of 10% remuneration rate on the investment costs.

As far as shareholders' NPV is considered, the cumulated value of all the free cash flows is actualized with the cost of equity and represents the excess value generated by the investment project on top of the remuneration set by the user as the “cost of equity”.

An $NPV = 0$ does not mean that the investment is not profitable, but it means that the capital investment remuneration is exactly equal to the discount rate applied in the cash flow actualisation.

Internal Rate of Return (IRR) is the key parameter that measures an investment profitability and is defined as the discount rate that breaks even the NPV.

IRR is the discount rate that balance all actualised cash out-flows (capital investments, operating, financial costs...) and in-flows (revenues...) and represents the specific rate of return of the investment project. It means that if a 12% IRR is calculated, the project is able to generate a 12% remuneration on capital investment.

Similarly, Levelised Cost Of Electricity (LCOE) is the electricity price that breaks even NPV calculation, meaning the minimum sale price that allow investors to recover their capital invested + a capital remuneration represented by the discount rate applied to the NPV calculation. Thus the LCOE is a function of the discount rate, with a positive correlation: the higher the capital investment remuneration required, the higher is the electricity sale price that allow to earn such remuneration.

LCOE is calculated by the file “LUEC_CALCULATOR3.m” on the basis of tentative values for the electricity price, sweeping steps in range between a minimum, maximum. The values of minimum, maximum and step are provided by default, but may be modified by the user being aware that widening the range and decreasing the step mean an increase in the number of iterations and therefore a higher calculation time needed.

When the LCOE calculation routine find two successive values that have different signs (positive/negative) it calculates a linear interpolation between them and retain the value crossing the abscissa axis as the LCOE value. INCAS provide an error estimation, which is represented by the actual value of the cash flows NPV assuming the LCOE as the electricity price.

IRR is calculated by the same mechanism by the file “IRR_CALCULATOR3.m”, with NPV curve decreasing with discount rate increasing, until crossing the abscissa axis. The interpolation of the two opposite value in the crossing region gives the IRR estimated value.

Pay Back Time (PBT) is the “break-even” time-period, where all cumulated cash inflows balance all investment costs; it is the period when the cumulated cash flows curve crosses the abscissa axis.

At PBT investors are able to recover their capital invested that is compensated by the cumulated value of cash in-flow. Usually discounting does not applies to PBT calculation, thus excluding the time-value of money.

In the INCAS code, the reference time $t=0$ for NPV and IRR calculation is assumed to be the beginning of construction of the first NPP of the fleet.

NPV, IRR, LCOE and PBT are calculated on the basis of the Free Cash Flows “to the Shareholders”. Cash flows are calculated in the “shareholders perspective”, considering net cash

flows after meeting financial debt obligations (interests and principal repayment). Coherently with the shareholders' perspective, the cost of equity is assumed as discount rate for the cash flows.

Consequently, the NPV has to be intended as an excess earning for the shareholders, above the capital remuneration rate represented by the cost of equity set for the calculation (input by the user, see "Input section")

IRR has to be considered as the actual remuneration rate for the equity capital invested.

LCOE is then the minimum electricity sale price (or electricity generation cost) that allow shareholders to recover the cost of equity.

PBT is the break even period for the cash flows to the shareholders (i.e. "Free cash flows").

The calculation of the NPV, IRR, LCOE and PBT of the investment project may also be run "at firm", that's to say considering the investors categories altogether (Shareholders and Lenders).

In this way, the calculation should considered cash flows before any debt obligation payment or financial income, including only all operating income and considering the whole capital investment (Debt+Equity).

In this case, Weighted Average Cost of Capital has to be assumed as discount rate for the "unlevered cash flows to the firm" actualisation.

It has to be highlighted that, as mentioned above, LCOE depends on the discount rate set for the actualisation: a higher discount rate as the "Cost of Equity" would bring to a higher LCOE to reach the capital remuneration required. Therefore LCOE from Free Cash Flows to the shareholder, such as the one calculated by INCAS, will be higher than LCOE from Unlevered Cash Flows to the firm, relying on the average cost of capital (Debt+Equity).

Tab.1. Definition of unlevered Cash Flows to the firm and Free Cash Flows to the shareholders

Cash flow to the firm	Cash flow to the shareholders
(-) CAPITAL EXPENDITURES	(-) EQUITY INVESTMENT
(+) EBIT	(+) EBIT
(-) TAX on EBIT	(+) DEPRECIATION
(+) DEPRECIATION	(-) TAX
CASH FLOW from operation	(+) INTEREST EARNINGS
(+) tax shield	(-) INTEREST EXPENSES
(+) INTEREST EARNINGS	(-) DEBT PRINCIPAL AMORTIZATION
CASH FLOW to the firm	FREE CASH FLOWS

Cash flows to the firm are net cash flows before any debt obligations (interest expenses and principal repayment), because we consider the whole investor-group point of view (shareholders and debt-holders). Thus, we consider the whole capital investments born by the investor group (Debt+Equity) and all the cash inflows generated by the project, before the allocation of the specific earnings to the two different investor categories. Essentially, it includes the income generated by the project, operational (cash flow from operations) and financial (interest earnings). The resulting cash flows are called "cash flows to the firm".

In the cash flow to the shareholders calculation, we consider only the capital investment born by shareholders and take into account only specific earnings of shareholders: i.e. subtracting interest expenses and debt principal obligations that represent debt-holders' earnings. The resulting cash flows are called "cash flows to the shareholders" or "free cash flow".

In addition, INCAS provides the calculation of other investment performance data such as:

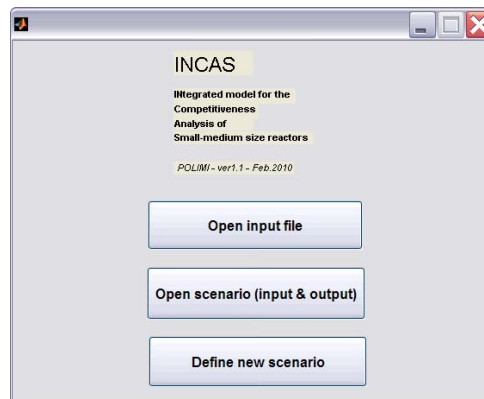
- ✓ Capital structure during the period lifetime: i.e. maximum and average Debt-to-Equity ratio; year where maximum Debt-to-Equity is realized.
- ✓ Net debt/EBITDA: it is a proxy of the number of years needed to repay the outstanding debt stock.
- ✓ Maximum financial exposure during construction period (maximum cash outlay in the cumulated cash flow curve) and the year when this condition is verified.
- ✓ Total Financial Interest Expenses, Interest During Construction representing only the amount due during the construction period.
- ✓ Total capital investment: overnight costs + Interests During Construction
- ✓ Total capital investment sources: Equity + Debt + Self-financing

Other selected time series values provide for a comprehensive understanding of the investment's financial performance:

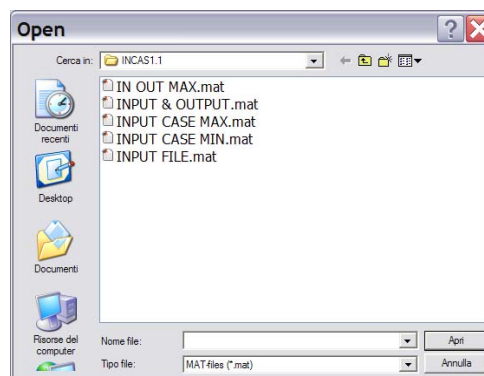
- ✓ Cumulated free cash flows on overall time-horizon
- ✓ Capital investment sources distribution on overall construction period
- ✓ Debt stock time evolution
- ✓ Cumulated free cash flows on overall time-horizon
- ✓ Single period free cash flows on overall time-horizon
- ✓ Total capital investment sources (Equity + Debt + Self-financing) for each NPP

All the above-mentioned output values are recorded in an output excel file, generated inside the folder of the “INCAS_MAIN.m” file.

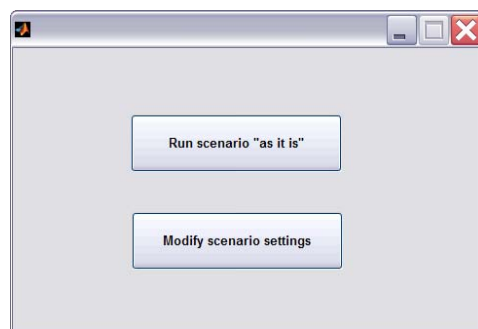
ANNEX I – INPUT PROCEDURE



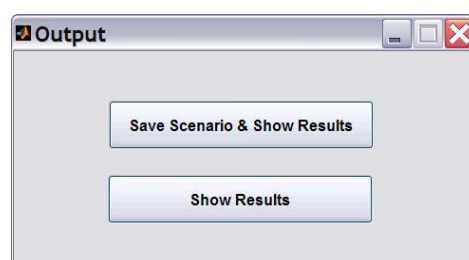
1. - If “Open input file”:



and after selecting the input file:



1.A - If “Run scenario ‘as it is’ ”: INCAS will perform the data processing.

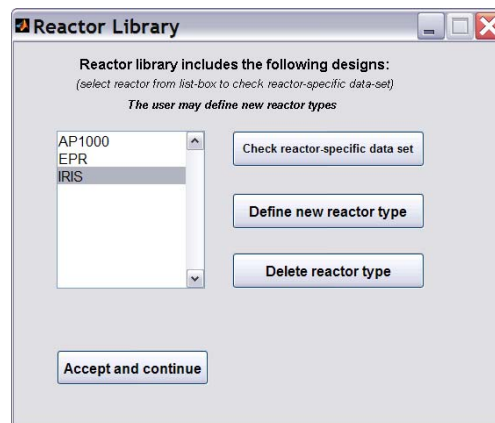


1.A.B - If “Save scenario & Show Results ”, the User will specify a file name for the data recording (Input+Output) and INCAS will generate and show the output (see INCAS OUTPUT), including the Excel file “INCAS_output.xls”.

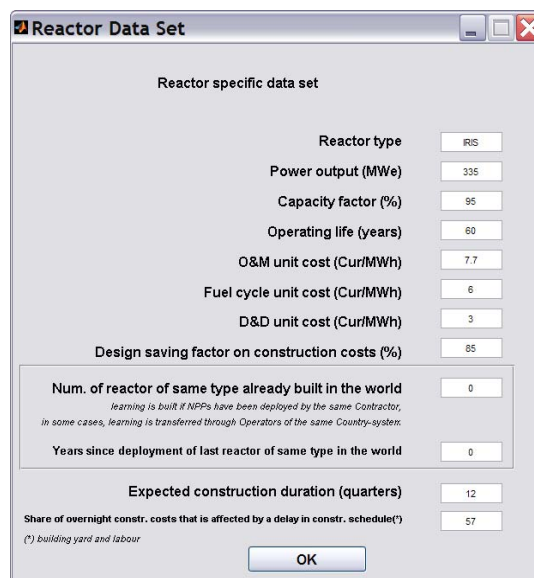
Warning: DO NOT DELETE or modify the “format_INCAS_output.xls” file, it must be present in the same INCAS software directory.

1.A.B - If “Show Results”, INCAS will generate the output (see INCAS OUTPUT) and will write it in the Excel file “INCAS_output.xls”.

1.B - If “Modify scenario settings”:



1.B.A - If the User selects a reactor name and “Check reactor specific data set”:



Reactor specific data set	
Reactor type	IRIS
Power output (MWe)	335
Capacity factor (%)	95
Operating life (years)	60
O&M unit cost (Cur/MWh)	7.7
Fuel cycle unit cost (Cur/MWh)	6
D&D unit cost (Cur/MWh)	3
Design saving factor on construction costs (%)	85
Num. of reactor of same type already built in the world <small>learning is built if NPPs have been deployed by the same Contractor, in some cases, learning is transferred through Operators of the same Country-system.</small>	0
Years since deployment of last reactor of same type in the world	0
Expected construction duration (quarters)	12
Share of overnight constr. costs that is affected by a delay in constr. schedule(*) <small>(*) building yard and labour</small>	57

OK

1.B.B - If the User selects “Define new reactor type”:

New Reactor Data Set

Reactor name	<input type="text"/>
Power output (MWe)	<input type="text"/>
Capacity factor (%)	<input type="text"/>
Operating life (years)	<input type="text"/>
O&M unit cost (Cur/MWh)	<input type="text"/>
Fuel cycle unit cost (Cur/MWh)	<input type="text"/>
D&D unit cost (Cur/MWh)	<input type="text"/>
Design saving factor on construction costs (%)	<input type="text"/>
Num. of reactor of same type already built in the world <small>learning is built if NPP has been deployed by the same Contractor, in some cases, learning is transferred through Operators of the same Country-system</small>	<input type="text"/>
Years since deployment of last reactor of same type, in the world	<input type="text"/>
Expected construction duration (quarters)	<input type="text"/>
Share of overnight constr. costs that is affected by constr. delay(*) <small>(*) building yard and labour</small>	<input type="text"/>

OK

1.B.C - If “Accept and continue”:

Investment Input

Investment specific inputs:
(User may change default values)

number of reactors	4
number of sites	1
cost of Equity (%)	13
Re-investment share (%)	100
Financing mix ratio (%): Equity / (Equity+Debt)	50
debt amortization period (years)	15
Cost of Debt (%)	8
average depreciation period for fixed assets (years)	12.5
overnight construction cost for a reference, standard large LWR (Cur/kWe)	3000
Power output of the reference, standard large LWR (MWe)	1000
annual escalation rate for construction cost (%)	2

< Back Continue >

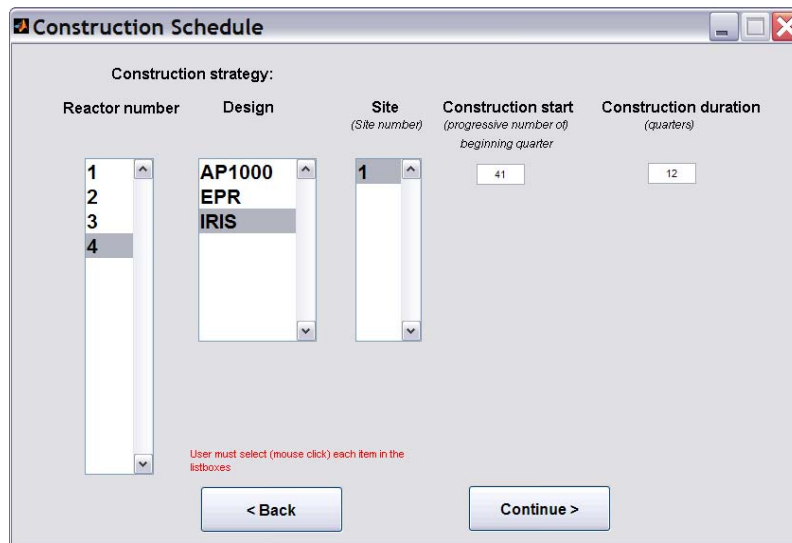
Country Input

Country specific inputs:
(User may change default values)

Electricity price(*) (Cur/kWh)	70
Electricity price annual increase rate (%)	2
Risk-free rate (real,%)	1
Annual inflation rate (%)	2
Corporate tax rate (%)	35

(*) Price paid to the Producer (i.e. NPP);

< Back Continue >



Construction Schedule

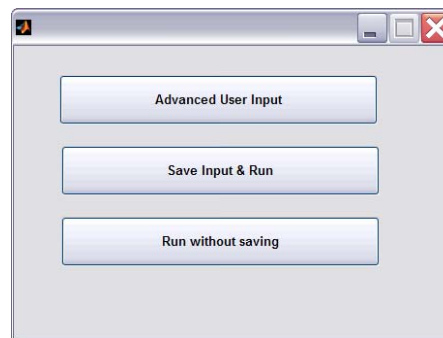
Construction strategy:

Reactor number	Design	Site (Site number)	Construction start (progressive number of beginning quarter)	Construction duration (quarters)
1	AP1000	1	41	12
2	EPR			
3	IRIS			
4				

User must select (mouse click) each item in the listboxes

< Back Continue >

The User can look at the input data for the Investment, Country and Construction Schedule input, for each reactor by selecting the reactor number.

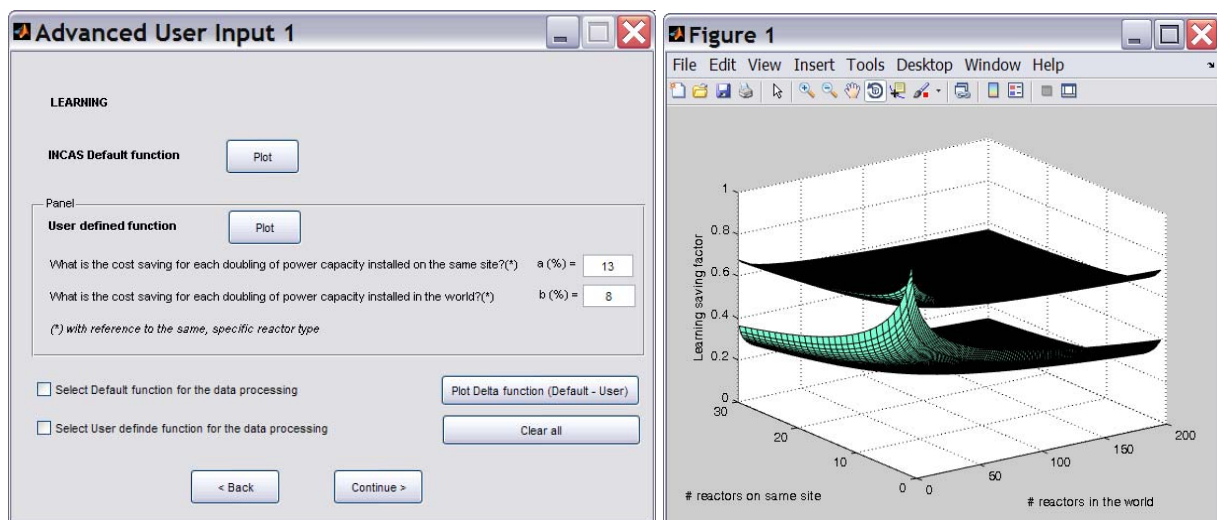


Advanced User Input

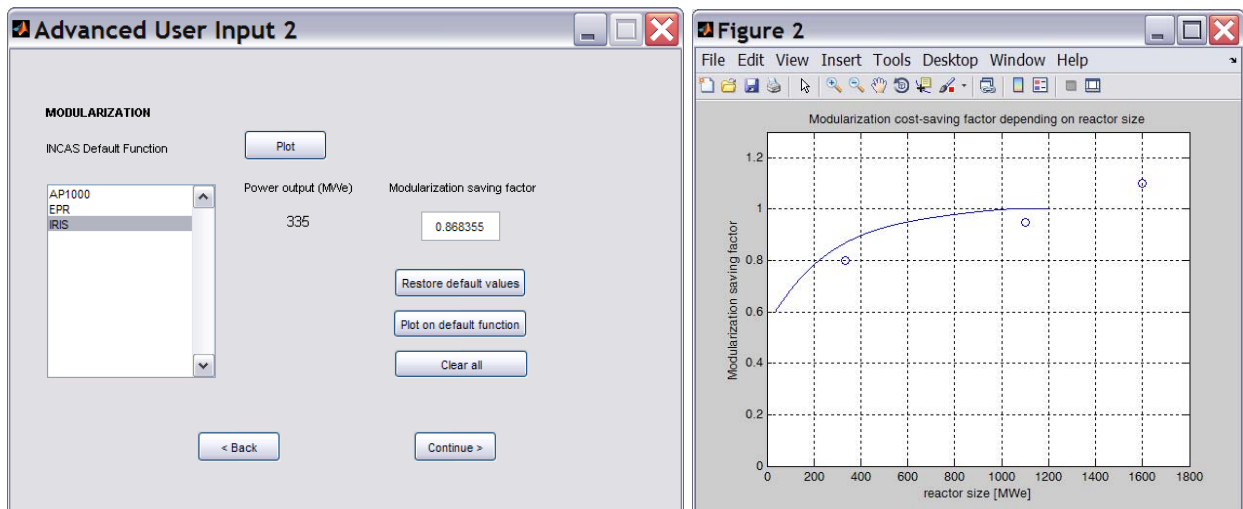
Save Input & Run

Run without saving

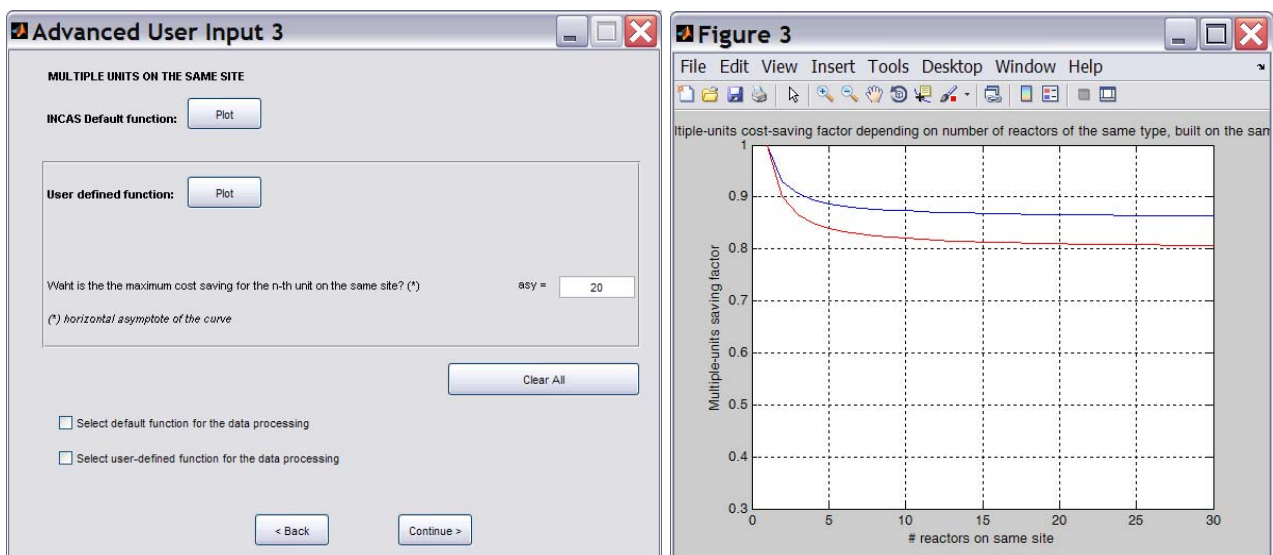
1.B.C.A - If “Advanced User Input”:



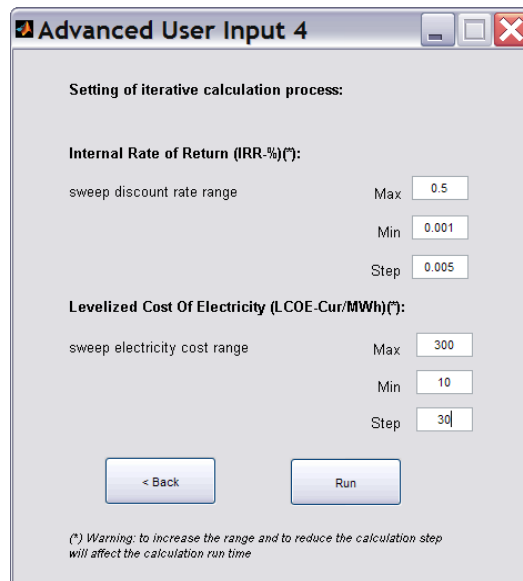
The User can plot INCAS default function for the Learning surface, or define a new Learning surface and plot both of them, looking at the difference by plotting the delta function.
The User can select the function to be used.



The User can plot INCAS default function for the Modularization curve, or define a new Modularization saving factor for each Reactor Type, looking at the difference by plotting the new data on the graph.



The User can plot INCAS default function for the “Multiple Units on the same Site” curve, or define a new function, looking at the difference by plotting both of them on the graph.
The User can select the function to be used.



Advanced User Input 4

Setting of iterative calculation process:

Internal Rate of Return (IRR-%)(^{*)}):

sweep discount rate range

Max

Min

Step

Levelized Cost Of Electricity (LCOE-Cur/MWh)(^{*)}):

sweep electricity cost range

Max

Min

Step

< Back Run

(^{*)} Warning: to increase the range and to reduce the calculation step will affect the calculation run time

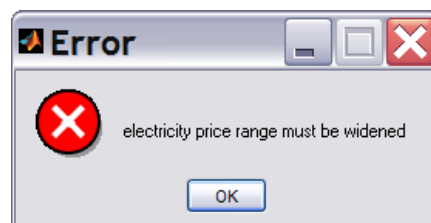
The User can select the range (Min to Max) and step for the calculation of the IRR and LCOE factors. The wider the range and the smaller the step, the longer the INCAS calculation time.

If INCAS is not able to find a convergence value for the IRR factor, the following error will appear:



The User must enlarge the range for convergence calculation and run the case again.

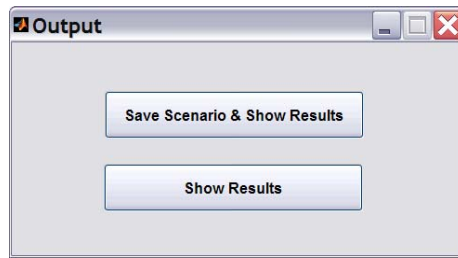
If INCAS is not able to find a convergence value for the LCOE factor, the following error will appear:



The User must enlarge the range for convergence calculation and run the case again.

1.B.C.B - If “Save Input & Run”, the User will specify a file name for the data recording; INCAS will perform the data processing.

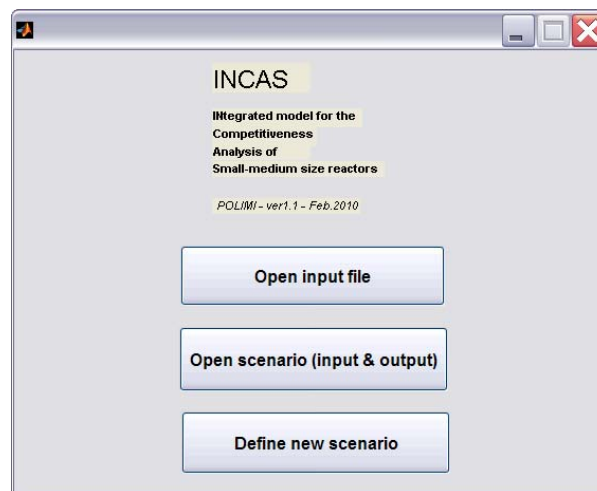
1.B.C.C - If “Run without saving”, INCAS will perform the data processing.



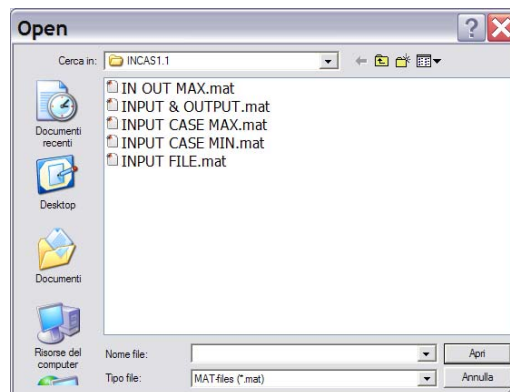
1.B.C.D - If “Save scenario & Show Results ”, the User will specify a file name for the data recording (Input+Output) and INCAS will generate and show the output (see INCAS OUTPUT), including the Excel file “INCAS_output.xls”.

Warning: DO NOT DELETE or modify the “format_INCAS_output.xls” file, it must be present in the same INCAS software directory.

1.B.C.E - If “Show Results”, INCAS will generate the output (see INCAS OUTPUT) and will write it in the Excel file “INCAS_output.xls”.



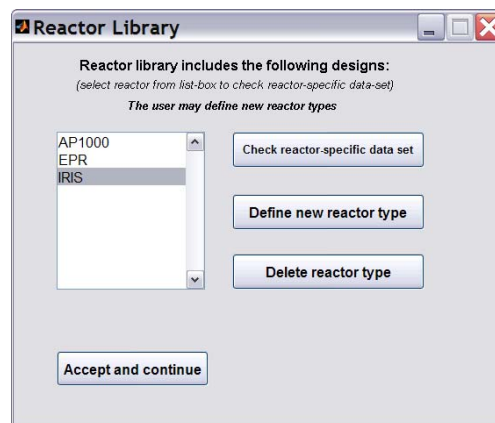
2. - If “Open scenario (input & output)”



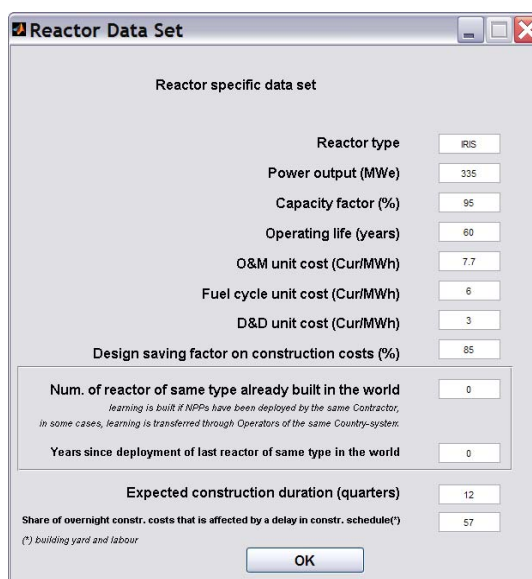
and after selecting the scenario file, INCAS will generate the output (see INCAS OUTPUT) and will write it in the Excel file “INCAS_output.xls”.



3. - If “Define new scenario”:



3.A - If the User selects a reactor name and “Check reactor specific data set”:

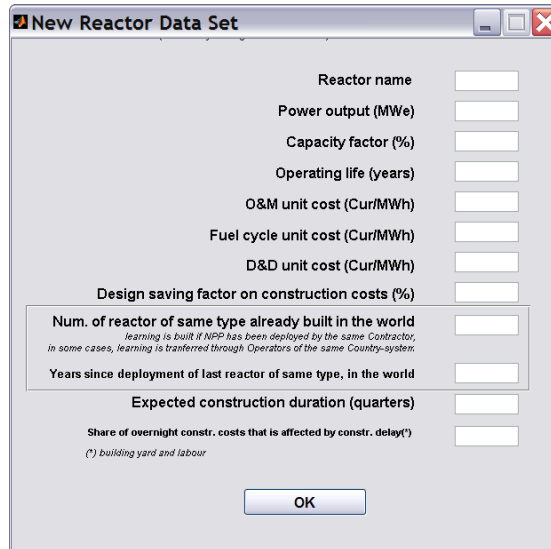


The Reactor Data Set window displays a form for entering reactor-specific data. The data is organized into a table with labels on the left and input fields on the right.

Reactor specific data set	
Reactor type	IRIS
Power output (MWe)	335
Capacity factor (%)	95
Operating life (years)	60
O&M unit cost (Eur/MWh)	7.7
Fuel cycle unit cost (Eur/MWh)	6
D&D unit cost (Eur/MWh)	3
Design saving factor on construction costs (%)	85
Num. of reactor of same type already built in the world <small>learning is built if NPPs have been deployed by the same Contractor, in some cases, learning is transferred through Operators of the same Country-system.</small>	0
Years since deployment of last reactor of same type in the world	0
Expected construction duration (quarters)	12
Share of overnight constr. costs that is affected by a delay in constr. schedule(*) <small>(*) building yard and labour</small>	57

OK

3.B - If the User selects “Define new reactor type”:



New Reactor Data Set

Reactor name

Power output (MWe)

Capacity factor (%)

Operating life (years)

O&M unit cost (Cur/MWh)

Fuel cycle unit cost (Cur/MWh)

D&D unit cost (Cur/MWh)

Design saving factor on construction costs (%)

Num. of reactor of same type already built in the world
learning is built if NPP has been deployed by the same Contractor,
in some cases, learning is transferred through Operators of the same Country-system

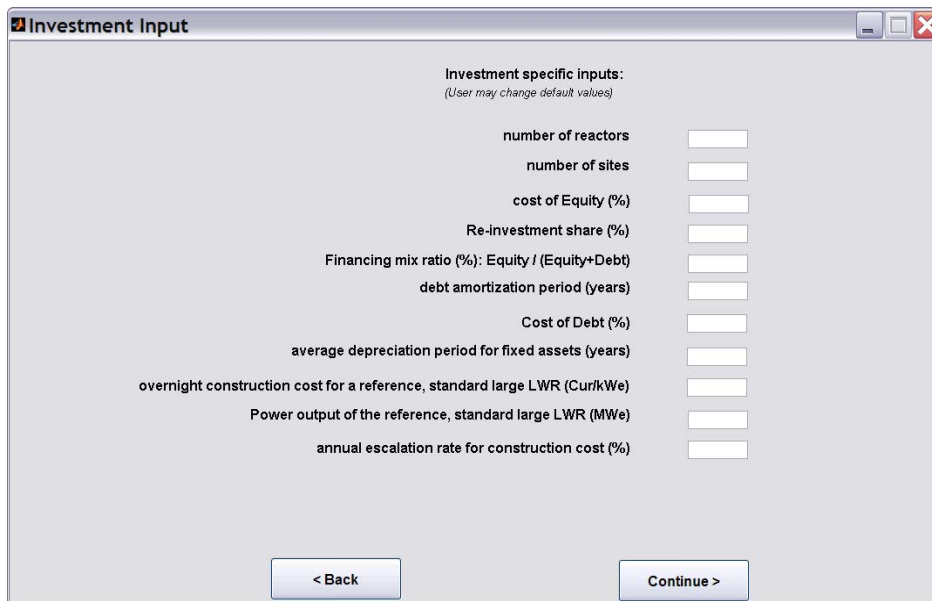
Years since deployment of last reactor of same type, in the world

Expected construction duration (quarters)

Share of overnight constr. costs that is affected by constr. delay(*)
(*) building yard and labour

OK

3.C - If “Accept and Continue”, the User defines scenario input values:



Investment Input

Investment specific inputs:
(User may change default values)

number of reactors

number of sites

cost of Equity (%)

Re-investment share (%)

Financing mix ratio (%): Equity / (Equity+Debt)

debt amortization period (years)

Cost of Debt (%)

average depreciation period for fixed assets (years)

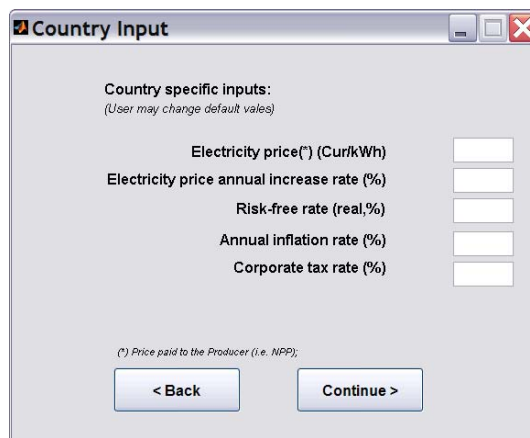
overnight construction cost for a reference, standard large LWR (Cur/kWe)

Power output of the reference, standard large LWR (MWe)

annual escalation rate for construction cost (%)

< Back

Continue >



Country Input

Country specific inputs:
(User may change default values)

Electricity price(*) (Cur/kWh)

Electricity price annual increase rate (%)

Risk-free rate (real,%)

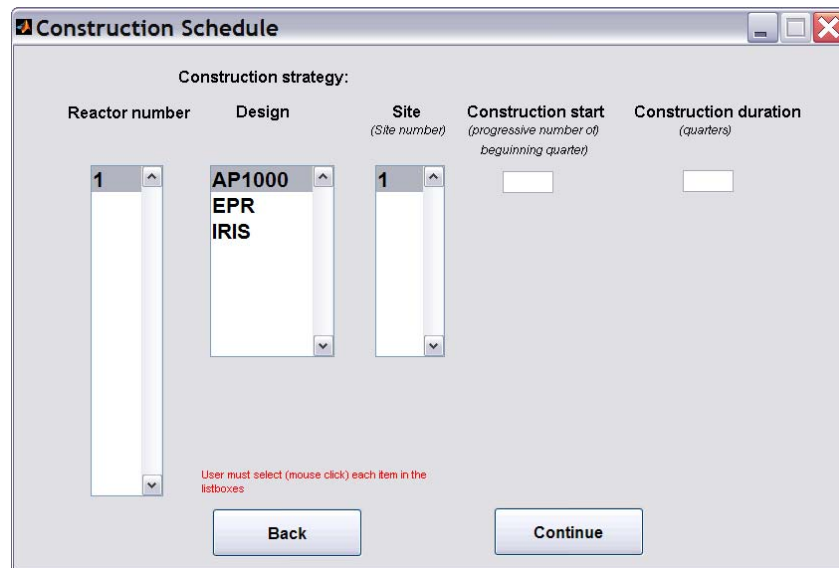
Annual inflation rate (%)

Corporate tax rate (%)

(*) Price paid to the Producer (i.e. NPP);

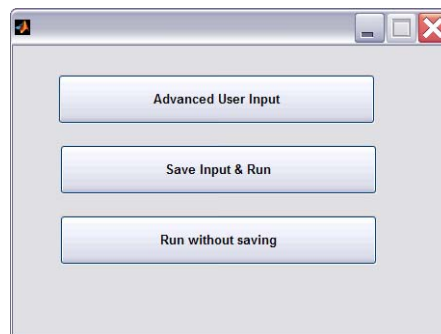
< Back

Continue >



The "Construction Schedule" window is titled "Construction strategy:". It contains five columns: "Reactor number", "Design", "Site", "Construction start", and "Construction duration". Each column has a listbox or input field. The "Reactor number" listbox shows "1". The "Design" listbox shows "AP1000", "EPR", and "IRIS". The "Site" listbox shows "1". The "Construction start" and "Construction duration" columns have empty input fields. Below the listboxes, a red text label reads: "User must select (mouse click) each item in the listboxes". At the bottom, there are "Back" and "Continue" buttons.

The User must select each Reactor number that will appear in the window (according to the data input in the previous windows) and for each Reactor must select the corresponding Design and the corresponding Site and input the Construction start and the Construction duration.

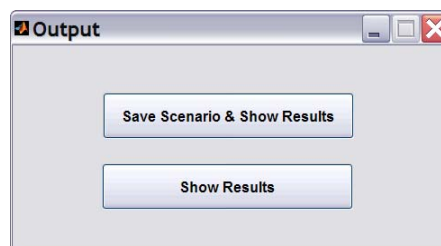


The "Advanced User Input" window contains three buttons: "Advanced User Input", "Save Input & Run", and "Run without saving".

3.C.A - If “Advanced User Input”: see 1.B.C.A

3.C.B - If “Save Input & Run”, the User will specify a file name for the data recording; INCAS will perform the data processing.

3.C.C - If “Run without saving”, INCAS will perform the data processing.



The "Output" window contains two buttons: "Save Scenario & Show Results" and "Show Results".

3.C.D - If “Save scenario & Show Results ”, the User will specify a file name for the data recording (Input+Output) and INCAS will generate and show the output (see INCAS OUTPUT), including the Excel file “INCAS_output.xls”.



Warning: DO NOT DELETE or modify the “format_INCAS_output.xls” file, it must be present in the same INCAS software directory.

3.C.E - If “Show Results”, INCAS will generate the output (see INCAS OUTPUT) and will write it in the Excel file “INCAS_output.xls”.

ANNEX II – INCAS OUTPUT

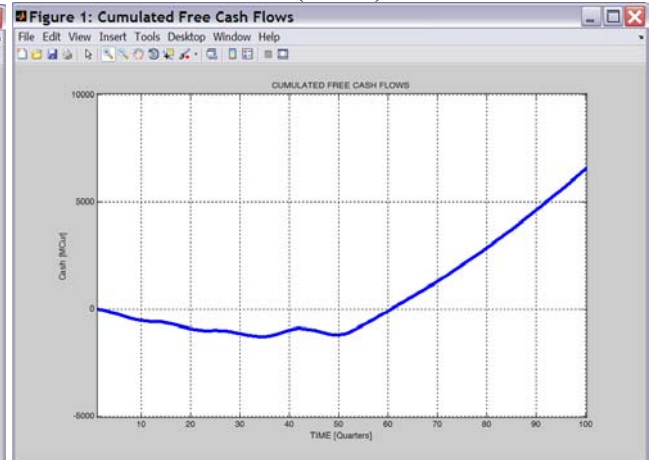
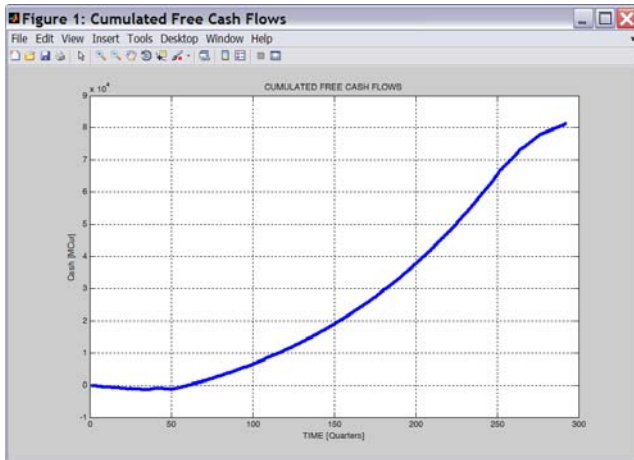
1. Graphical Output:

INCAS Output 1	
NPV(MCur)	259.161
Total Financial Interests.....(MCur)	871.791
of which:	
Interest During Construction.....(MCur)	153.281
Overnight Capital Expenditures....(MCur)	3876.49
Total self-financing.....(MCur)	1450.78
Total Equity investment.....(MCur)	1212.85
Total Debt investment.....(MCur)	1366.13

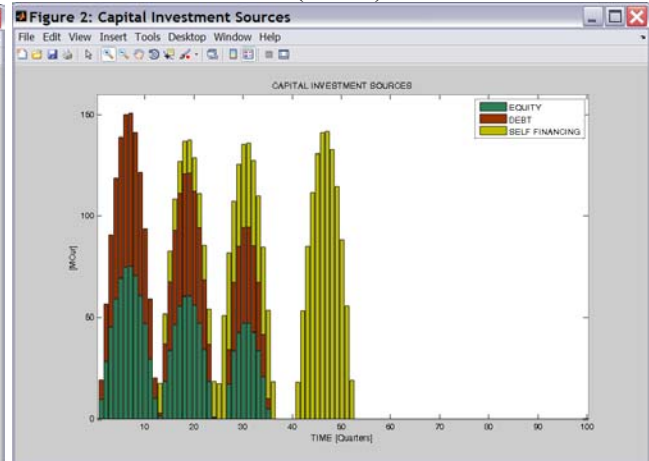
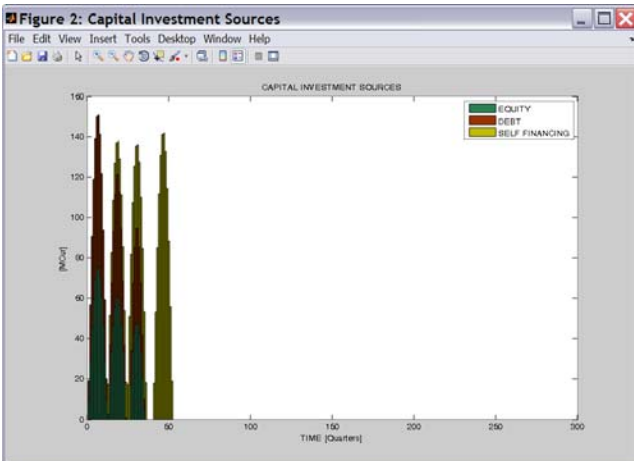
INCAS Output 2	
Pay Back Time.....(year)	15.25
<small>When cumulated cash flows are = 0 negative cumulated cash flows equal positive cumulated cash flows</small>	
<small>Cash Flow</small>	
Maximum cash outlay.....(MCur)	-1304.7
<small>Maximum negative value of cumulated cash flow curve</small>	
Maximum cash outlay.....(year)	8.75
Average Debt/Equity.....(%)	37.6084
<small>on Balance Sheet</small>	
<small>Financing mix</small>	
Maximum Debt/Equity(%)	112.834
<small>on Balance Sheet</small>	
Maximum Debt/Equity.....(year)	3
<small>*critical year*</small>	
Debt coverage ratio.....	4.03702
<small>Debt stock / EBITDA</small>	

INCAS Output3	
IRR-Internal Rate of Return.....%	14.539
LCOE-Levelized Cost Of Electricity...(Cur/MWh)	62.720
Conv.Error (actual NPV at LCOE).....(MCur)	14.656
Conv.Error (actual NPV at IRR).....(MCur)	-4.237

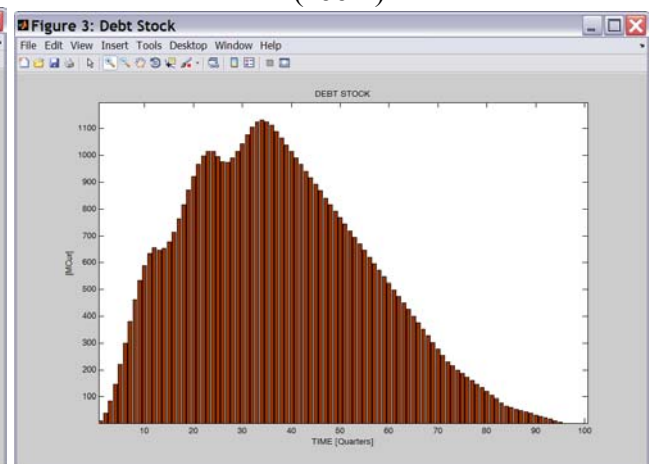
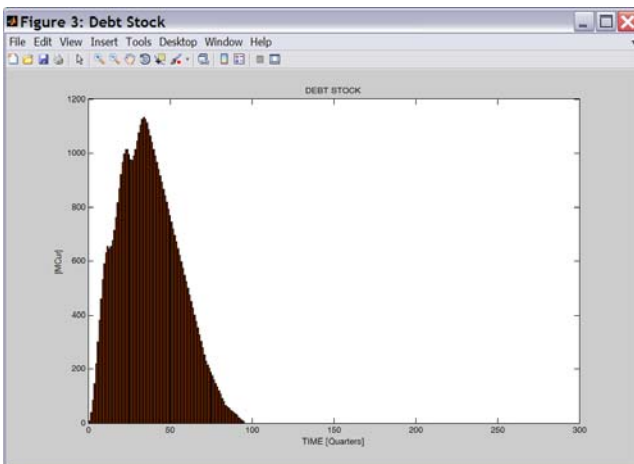
(zoom)

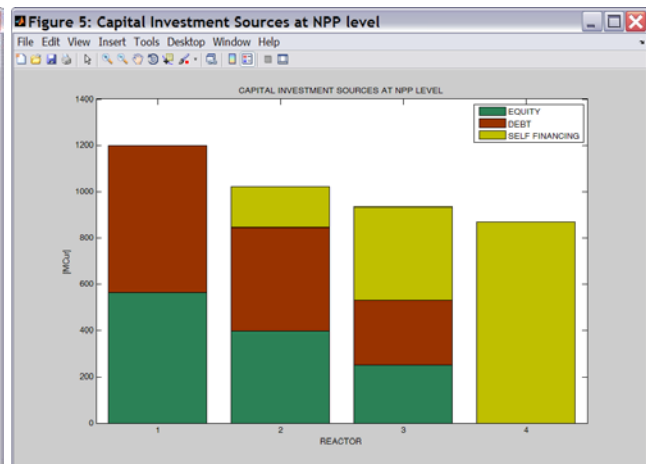
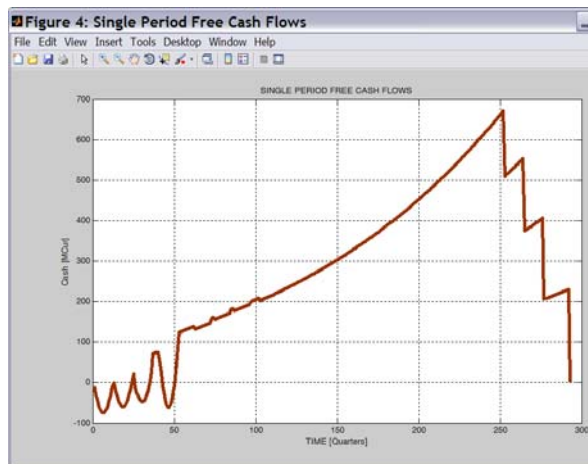


(zoom)



(zoom)





2. Excel file Output (“INCAS_output.xls”):

1	REACTOR	REACTOR TYPE	REACTOR POWER	SITE	Construction Start	Construction Period	NPV Net Present Value	Pay Back Time	IRR Internal Rate of Return					
2	[#]	[name]	[MW]	[#]	[quarters]	[quarters]	[M€]	[years]	[%]					
3	1	RIS	335	1	1	12	259.1806786	16.25	14.53960538					
4	2	RIS	335	1	13	12	Total Financial Interests	Maximum Cash Outlay	LCOE Levelized Cost Of Electricity					
5	3	RIS	335	1	25	12	[M€]	[M€]	[€/MWh]					
6	4	RIS	335	1	41	12	871.7908133	-1304.70487	62.72685078					
7							(of which) Interest During Construction	Maximum Cash Outlay @	Convergence Error on NPV for IRR calculation					
8							[M€]	[year]	[M€]					
9							163.2812596	8.76	-4.237842544					
10							Overnight Capital Expenditures	Average Debt/Equity	Convergence Error on NPV for LCOE calculation					
11							[M€]	[%]	[M€]					
12							3876.486121	37.60837092	14.65650222					
13							Total Self Financing	Maximum Debt/Equity						
14							[M€]	[M€]						
15							1450.780638	112.8338208						
16							Total Equity Investment	Maximum Debt/Equity @						
17							[M€]	[year]						
18							1212.862791							
19							Total Debt Investment	Debt Coverage Ratio						
20							[M€]	[€]						
21							1366.134051	4.037023048						

1	TIME	Cumulated Free Cash Flows	Total Equity Investment	Total Debt Investment	Self Financing	Total Debt Stock	Single Period Free Cash Flows	REACTOR	REACTOR TYPE	NPV Source of Investment: Equity	NPV Source of Investment: Debt	NPV Source of Investment: Self Financing
2	QUARTERS	[M€]	[M€]	[M€]	[M€]	[M€]	[M€]	[#]	[name]	[M€]	[M€]	[M€]
3	1	-9.622690592	9.622690592	9.622690592	0	9.71888389	-9.622690592	1	RIS	564.8084484	636.4142601	176.562
4	2	-37.97606341	28.35336282	28.35336282	0	38.55691083	-28.35336282	2	RIS	397.517726	448.121209	454.668
5	3	-43.36269692	45.3202521	45.3202521	0	85.2199526	-45.3202521	3	RIS	250.5266172	281.598582	870.149
6	4	-142.6741998	59.36954121	59.36954121	0	146.8108651	-59.36954121	4	RIS	0	0	0
7	5	-212.1577814	69.48298154	69.48298154	0	219.9615709	-69.48298154					
8	6	-287.9950273	74.93724592	74.93724592	0	300.094268	-74.93724592					
9	7	-382.4689584	75.31932315	75.31932315	0	382.2347002	-75.31932315					
10	8	-432.9374056	70.53044617	70.53044617	0	461.1994882	-70.53044617					
11	9	-493.8061021	60.8889652	60.8889652	0	532.0051814	-60.8889652					
12	10	-440.7448267	46.93972453	46.93972453	0	590.1615229	-46.93972453					
13	11	-670.4009088	29.65508213	29.65508213	0	632.0386062	-29.65508213					
14	12	-580.566279	10.16537024	10.16537024	0	655.0751136	-10.16537024					
15	13	-582.0710339	1.604754003	1.604754003	14.56465468	645.6771494	-1.604754003					
16	14	-600.5442308	18.47319681	18.47319681	14.8360732	653.4497315	-18.47319681					
17	15	-634.3031016	33.83887081	33.83887081	16.1081374	677.120782	-33.83887081					
18	16	-680.9067271	46.52325241	46.52325241	15.20805051	714.3034835	-46.52325241					
19	17	-736.5288864	55.62215928	55.62215928	15.65421578	761.648353	-55.62215928					
20	18	-796.9944662	60.46577973	60.46577973	15.92823645	815.0627944	-60.46577973					
21	19	-857.6655558	60.67058953	60.67058953	16.20291584	869.983758	-60.67058953					
22	20	-913.8139001	56.1666442	56.1666442	16.4782572	921.6853603	-56.1666442					
23	21	-961.0377916	47.20589145	47.20589145	16.75426386	965.600738	-47.20589145					
24	22	-995.3636278	34.34813611	34.34813611	17.03093915	997.6362775	-34.34813611					
25	23	-1013.81117	18.42577173	18.42577173	17.30828864	1014.456266	-18.42577173					
26	24	-1014.301182	0.89484247	0.89484247	17.58630897	1013.719204	-0.89484247					
27	25	-993.4661599	0	0	17.38151828	994.6402999	-20.8352211					
28	26	-1006.839115	0	0	51.21483327	975.5611961	-12.37265633					
29	27	-1031.356734	17.0555208	17.0555208	47.76728542	973.7103226	-26.51761943					
30	28	-1065.081809	33.72517451	33.72517451	39.78917575	989.0452881	-33.72517451					
31	29	-1107.677579	42.5968696	42.5968696	40.71614784	1014.036578	-42.5968696					
32	30	-1154.9351	47.25752136	47.25752136	40.84451162	1044.625099	-47.25752136					
33	31	-1202.266139	47.33103904	47.33103904	41.37427403	1076.292281	-47.33103904					
34	32	-1245.015182	42.74742497	42.74742497	41.90544206	1104.354338	-42.74742497					
35	33	-1278.7679	33.75471718	33.75471718	42.43802279	1124.280558	-33.75471718					
36	34	-1299.675628	20.90772808	20.90772808	42.97202322	1132.028149	-20.90772808					
37	35	-1384.70487	5.02934272	5.02934272	43.50745048	1124.273793	-5.02934272					
38	36	-1279.02422	0	0	18.38795348	1111.668072	25.68248114					
39	37	-1207.529421	0	0	1087.140906	71.49300133	71.49300133					
40	38	-1134.928395	0	0	1062.613741	72.60102597	72.60102597					
41	39	-1061.21171	0	0	1038.086575	73.71658496	73.71658496					
42	40	-986.3716832	0	0	1013.559409	74.84002684	74.84002684					
43	41	-928.4986334	0	0	18.09805049	989.032436	57.87304981					
44	42	-804.8038168	0	0	53.32610323	964.0505779	23.69416555					
45	43	-912.1527203	0	0	85.2537278	939.9779122	-7.348903444					
46	44	-845.1748199	0	0	111.6603453	915.4507466	-33.02209967					
47	45	-696.6088668	0	0	130.6813823	890.8235809	-51.437176682					
48	46	-1057.779507	0	0	140.935693	866.3964152	-61.17022057					

Note: It is wise to rename the INCAS_output.xls file (e.g. to INCAS_SCENARIOxxxx_output.xls) to save the results of a run, to avoid

ANNEX III – TRIAL TEST OF INCAS

Hereafter we report about a trial test of INCAS on the “Low Variant scenario” delivered by ENEA as an “Italian Case Study” in the framework of the IAEA “*Coordinated Case Studies on Competitiveness of SMR in Different Applications: Case Study Italy*”. The scenario inputs are the following.

Capital costs (overnight construction costs) and cost of capital (cost of debt and equity) are defined by a range of values, thus producing further variants depending on the combinations of maxima/minima.

Hereafter, we identify and analyse the two different cases:

- ✓ Case “MAX”, corresponding to the highest capital cost (3,500 €/kWe) and to the highest cost of capital (cost of equity=15%; cost of debt=8%; with 50% debt on total capital employed)
- ✓ Case “MIN”, corresponding to the lowest capital cost (2,000 €/kWe) and to the lowest cost of capital (cost of equity=10%; cost of debt=6%; with 80% debt on total capital employed)

Scenario inputs

1.Reactor-specific inputs:

reactor type	EPR	IRIS
power output (MWe)	1600	335
capacity factor	90%	90%
O&M cost (€/MWh)	7,90	7,92
Fuel cycle cost (€/MWh)	6,65	6,67
Decommissioning cost (€/MWh)	1,06	0,88
expected construction period for n th unit	5 years	3 years
operating life	60 years	60 years
design saving factor on capital costs	100%	80%
cumulated capital expenditure profile	S' curve	S' curve

2.Country-specific inputs:

Inflation rate	0%
Electricity price increase rate	0%
Corporate tax rate	35%

3.Investment-specific inputs:

cost of equity	15%	10%
cost of debt	8%	6%
financing mix: D/(D+E)	50%	80%
debt amortization period	10 years	10 years
depreciation period for fixed assets	12.5 years	12.5 years
escalation rate for capital costs	0%	0%

This case study considers all the fleet of 6 EPR and 16 IRIS. INCAS calculates the capital cost for each NPP based on a reference cost for a stand alone LWR of a given power output. For the purpose of this analysis, we therefore assume the first EPR of the fleet as the reference LWR and derive the cost of other NPP depending on the scale factor, on the learning effect in the construction of subsequent units of the same kind, on the fixed costs sharing by multiple units on a single site, on the modularization cost savings and on the design cost savings.

Depending on capital costs we consider two cases:

	EPR	
	min	max
overnight capital cost (€/kWe)	2000 €/kWe	3500 €/kWe

4. Construction schedule:

ITALY_SCENARIO2_2014-30 Low Variant (LR&SMRs)																	
Reference inputs: 340 TWh electricity demand in 2007; prospected ave. growth rate=1.0%/y Nuclear generation target (min) = 25% demand of electricity at 2030 = 106 TWh 6 EPR installed=9.6 GWe=75.6 TWh (1EPR=12.6TWh/y, 1.6 GWe at 90% capacity factor) 8 Twin-IRIS installed=5.36 GWe=42.2 TWh (1 IRIS=2.64TWh/y, 0.335 GWe at 90% capacity factor) Construction time EPR: 7 yr for the first 2 units; 6 yr for the 3-rd unit; 5 yr from the 4-th unit on Construction time IRIS : 4 yr for the first 4 modules; 3 yr from the 5-th module on																	
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EPR_1																	
EPR_2																	
EPR_3																	
EPR_4																	
EPR_5																	
EPR_6																	
IRIS_1																	
IRIS_2																	
IRIS_3																	
IRIS_4																	
Capacity (GWe)							1,60	3,20		5,47	7,74	9,34	11,61	12,28	12,95	13,62	14,96

(ENEA - “Coordinated Case Studies on Competitiveness of SMR in Different Applications: Case Study Italy”)

This construction schedule corresponds to the following input table for INCAS: →

We consider that no more than 2 EPR may be hosted on a single nuclear site in Italy; the IRIS NPP are distributed on 2 sites (8 units each).

Therefore 5 sites are needed: 3 for the 6 EPR (3,200MWe each) and 2 for the 16 IRIS (2,680MWe each).

We highlight that the construction of first 3 EPR has a delay as compared to the expected duration of construction for this kind of reactor-plant: 7 and 6 years against 5 years expected for a n-th of a kind.

The same happens for the first IRIS 4 units, with 1 year delay as compared to 3 years expected construction period for a n-th of a kind.

#	REACTOR TYPE	SITE	START quarter	DURATION quarter
1	EPR1	1	1	28
2	EPR2	1	5	28
3	EPR3	2	17	24
4	EPR4	2	25	20
5	EPR5	3	29	20
6	EPR6	3	33	20
7	IRIS1	4	25	16
8	IRIS2	4	25	16
9	IRIS3	4	29	16
10	IRIS4	4	29	16
11	IRIS5	4	41	12
12	IRIS6	4	41	12
13	IRIS7	4	45	12
14	IRIS8	4	45	12
15	IRIS9	5	49	12
16	IRIS10	5	49	12
17	IRIS11	5	53	12
18	IRIS12	5	53	12
19	IRIS13	5	57	12
20	IRIS14	5	57	12
21	IRIS15	5	57	12
22	IRIS16	5	57	12

Simulation results

Hereafter we will report the results related to the Case MIN and Case MAX of the ENEA's Italian "Low Variant" scenario, with:

CASE MIN:

- ✓ capital cost=2000€/kWe for a reference 1000 LWR,
- ✓ 6% cost of debt,
- ✓ 10% cost of equity
- ✓ 80% debt on total capital employed.

CASE MAX:

- ✓ capital cost=3000€/kWe for a reference 1000 LWR,
- ✓ 8% cost of debt,
- ✓ 15% cost of equity
- ✓ 50% debt on total capital employed.

The location of each NPP on the national sites has a relevant impact on the economics of the whole investment project because learning and site-related fixed-costs sharing are cost-saving factors that depend on the number of units of the same kind that are built on the same site.

As a consequence, construction cost reduction applies as much as the number of NPP of the same type on the same site is higher.

The construction costs of the EPR and IRIS fleets give an interesting example on how "economy of multiples" may contribute to compensate dis-economy of scale.

The table besides shows the unit overnight costs of each EPR and IRIS plant, in the Case MAX.

The cost of a reference, standard 1,600MWe LWR is assumed to be 3,500 €/kWe; due to the economy of scale, the cost of the first EPR (1,600MWe) would be lower than reference LWR (that's to say lower than 3500€/kWe), but delay in the construction period increase unit costs above 4000€/kWe for first 3 EPR units.

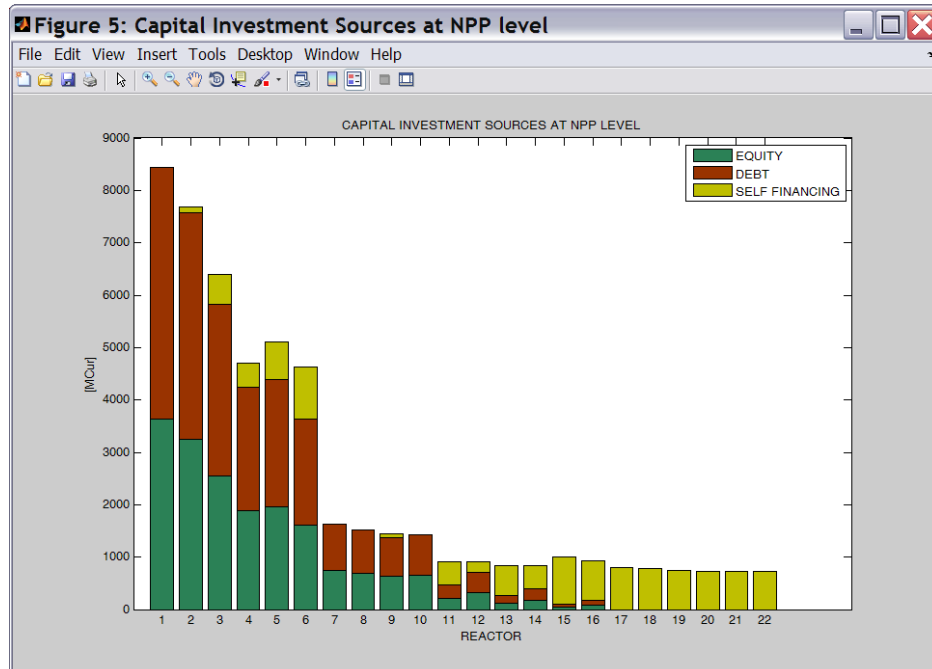
The same applies to first IRIS units 1-4, that bear a construction delay and dis-economy of scale as compared to EPR.

Learning accumulation on the construction activity allows to decrease construction costs for both multiple EPR and IRIS NPP.

Co-siting economies (fixed costs sharing) contribute to decrease capital costs for NPPs on the same site.

On account of site changes, construction costs present discontinuities: the first NPP on a new site bears all the fixed, site-related costs. Successive NPP on the same site will benefit of cost reduction from fixed costs sharing.

	€/kWe
EPR1	4851
EPR2	4509
EPR3	4056
EPR4	3141
EPR5	3477
EPR6	3232
IRIS1	5241
IRIS2	4872
IRIS3	4749
IRIS4	4687
IRIS5	3265
IRIS6	3248
IRIS7	3116
IRIS8	3107
IRIS9	3835
IRIS10	3565
IRIS11	3187
IRIS12	3146
IRIS13	2993
IRIS14	2977
IRIS15	2966
IRIS16	2957



Capital Investment Sources at NPP level, CASE MAX

Overnight cost of EPR1 and 2 bear 2 year construction delay; the delay is 1 year for the 3rd EPR.

Construction costs decrease until EPR4 on account of learning accumulation. EPR 4 benefit from meeting its construction schedule (5 years) and from fixed costs sharing with EPR 3, on the same site.

EPR5 costs are higher than for previous EPR4 due to a site change that prevents EPR5 from sharing site-related costs with previous NPP units and due to a stop in the learning accumulation:

construction schedule shows that EPR5 and 6 are built before that 1/3 completion of previous NPP, which is a condition for INCAS to account for learning accumulation.

Construction costs of EPR 5 then benefit from a “worldwide” learning experience, built through the construction of 4 EPR units outside of the current site.

Construction of IRIS11 meets its 3 year schedule, thus decreasing significantly construction costs as compared to previous 4 units.

IRIS15 shows a discontinuity due to a site change: this unit has to bear all the site-related fixed costs and is not able to benefit from any on-site learning accumulation. Successive IRIS unit from 16 to 22, will benefit from on-site learning effect and site-related fixed costs sharing, showing a constant, regular cost decrease.

INCAS results show that high capital costs and high cost of debt in the MAX case account for a high LCOE as compared to MIN case.

With an electricity price of 70 €/MWh NPV is negative in MAX case, that means that the investment cannot reach 15% of remuneration rate for shareholders (IRR is actually 13.4%).

Either the electricity price must be higher than LCOE (i.e. higher than 80 €/MWh) to grant such a profitability, or the capital remuneration required must be lower than IRR to generate positive NPV.

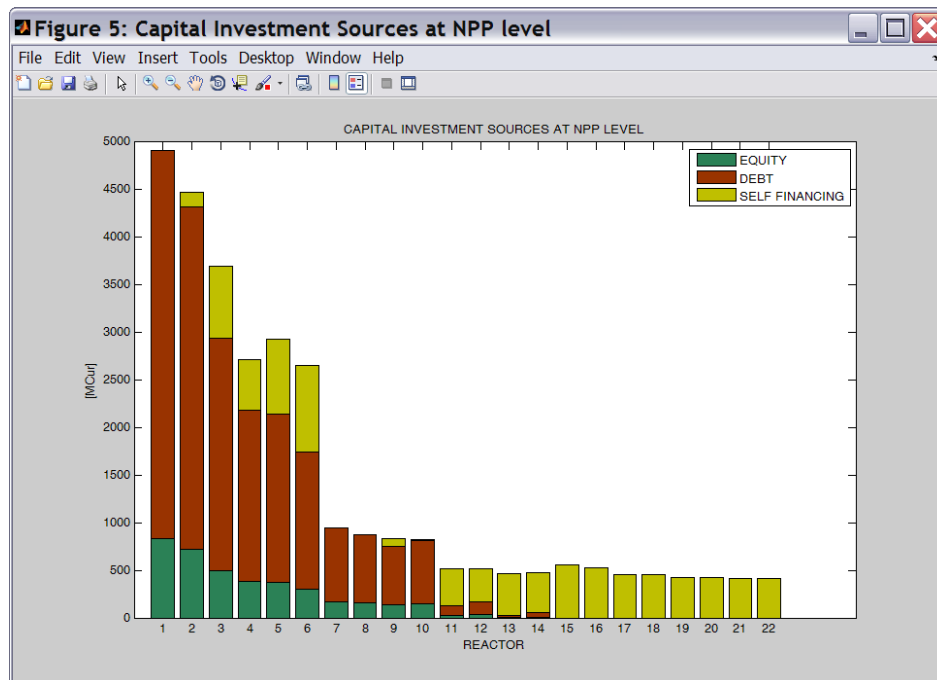
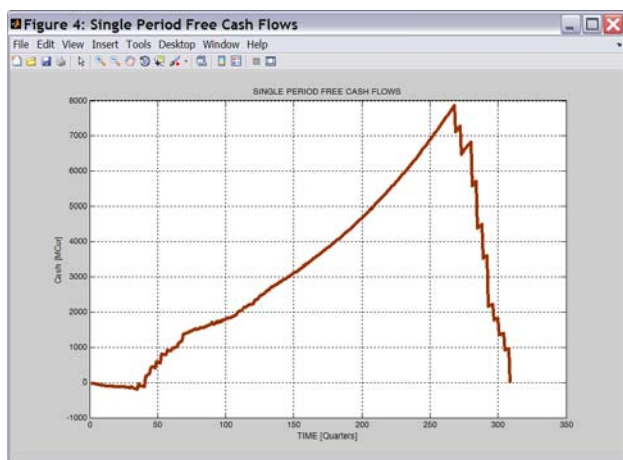
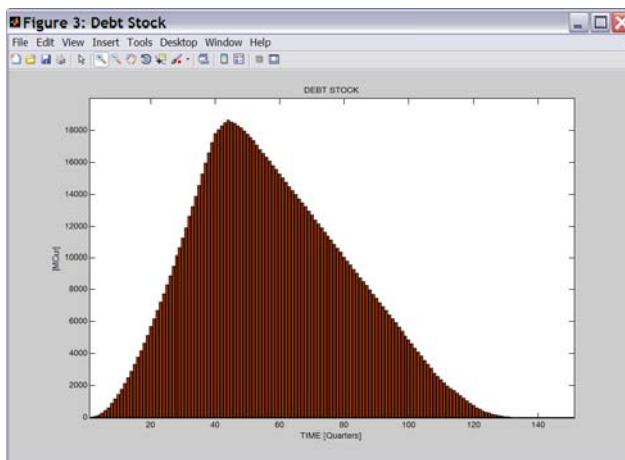
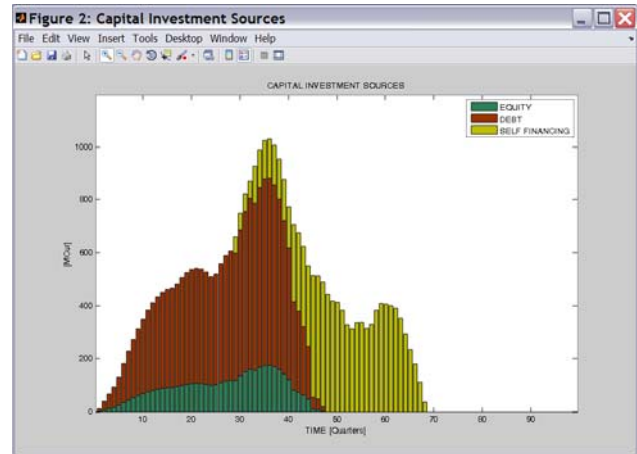
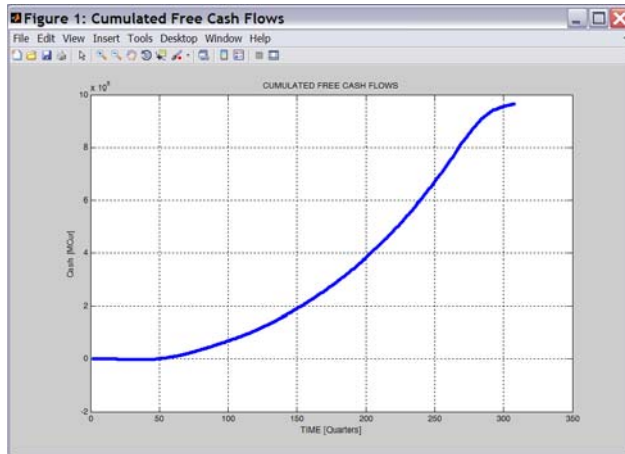
**LOW VARIANT – CASE MIN**

INCAS Output 1		
NPV	(MCur)	18894.9
Total Financial Interests.....	(MCur)	12124.5
of which:		
Interest During Construction.....	(MCur)	3106.98
Overnight Capital Expenditures...	(MCur)	27397.6
Total self-financing.....	(MCur)	8480.35
Total Equity investment.....	(MCur)	3783.45
Total Debt investment.....	(MCur)	18240.8

INCAS Output 2		
Pay Back Time.....	(year)	12.5
<small>When cumulated cash flows are = 0 negative cumulated cash flows equal positive cumulated cash flows</small>		
<small>Cash Flow</small>		
Maximum cash outlay.....	(MCur)	-3564.79
<small>Maximum negative value of cumulated cash flow curve</small>		
Maximum cash outlay.....	(year)	10
Average Debt/Equity.....	(%)	83.2874
<small>on Balance Sheet</small>		
<small>Financing mix</small>		
Maximum Debt/Equity	(%)	470.241
<small>on Balance Sheet</small>		
Maximum Debt/Equity.....	(year)	7
<small>"critical year"</small>		
Debt coverage ratio.....		3.28069
<small>Debt stock / EBITDA</small>		

INCAS Output3		
IRR-Internal Rate of Return.....	%	26.091
LCOE-Levelized Cost Of Electricity...	(Cur/MWh)	35.268
Conv.Error (actual NPV at LCOE).....	(MCur)	373.79
Conv.Error (actual NPV at IRR).....	(MCur)	-6.478

In this case we have set the step for LCOE calculation at 10 Cur/MWe to sweep the tentative range. This produces an error of nearly 2% in the LCOE calculation. To obtain more refined estimation of LCOE, a thinner step should be set (i.e. 2 Cur/MWe).



Self-financing gives a significant contribution to the investment funding and is able to cover the capital costs of later IRIS NPP units.

LOW VARIANT – CASE MAX

NPV is negative: it means that the investment project cannot grant a remuneration of 15% (cost of Equity). Investment profitability, represented by the IRR, is actually 11.7%, lower than the cost of Equity.

INCAS Output 1	
NPV	(MCur) -1979.43
Total Financial Interests.....	(MCur) 20593.9
of which:	
Interest During Construction.....	(MCur) 4990.92
Overnight Capital Expenditures....	(MCur) 47945.8
Total self-financing.....	(MCur) 10782.2
Total Equity investment.....	(MCur) 18581.8
Total Debt investment.....	(MCur) 23572.7

INCAS Output 2	
Pay Back Time.....	(year) 17.5
When cumulated cash flows are = 0 negative cumulated cash flows equal positive cumulated cash flows	
Cash Flow	
Maximum cash outlay.....	(MCur) -19105.4
Maximum negative value of cumulated cash flow curve	
Maximum cash outlay.....	(year) 11
Average Debt/Equity.....	(%) 38.2341
on Balance Sheet	
Financing mix	
Maximum Debt/Equity	(%) 124.561
on Balance Sheet	
Maximum Debt/Equity.....	(year) 8
"critical year"	
Debt coverage ratio.....	4.38893
Debt stock / EBITDA	

INCAS Output3	
IRR-Internal Rate of Return.....	% 13.404
LCOE-Levelized Cost Of Electricity....	(Cur/MWh) 79.911
Conv.Error (actual NPV at LCOE).....	(MCur) 2.9705
Conv.Error (actual NPV at IRR).....	(MCur) -245.2

